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CHARLES F. MARVIN, Chief

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INTRODUCTION.

The MONTHLY WEATHER REVIEW contains (1) meteorological contributions and bibliography including seismology; (2) an interpretative summary and charts of the weather of the month in the United States and on the adjacent oceans; and (3) climatological and seismological table dealing with the weather and earthquakes of the month.

The contributions are principally as follows: (a) Results of the observational or research work in meteorology carried on in the United States or other parts of the world, in the Weather Bureau, at universities, at research institutes, or by individuals; and (b) abstracts or reviews of important meteorological papers and books, and (c) notes. In each issue of the REVIEW reviews, abstracts, and notes are grouped by subjects, roughly, in the following order: General works, observations and reductions, physical properties of the atmosphere, temperature, pressure, wind, moisture, weather; applications of meteorology, climatology, and seismology.

The Weather Bureau desires that the MONTHLY WEATHER REVIEW shall be a medium of publication for contributions within its field, but the publication of such contributions is not to be construed as official approval of the views expressed.

The partly annotated bibliography of current publications is prepared in the Weather Bureau Library. Persons or institutions receiving Weather Bureau publications free should send in exchange a copy of anything they may publish bearing upon meteorology, addressed "Library U. S. Weather Bureau, Washington, D. C.," in order that the monthly list of current works on meteorology and seismology may be as complete as possible. Similar contributions from others will be welcome. Bibliographies of selected subjects are published from time to time in the REVIEW.

The section on the weather of the month contains (1) an interpretative discussion of the weather of North America and adjacent oceans, and some notes on the weather in other parts of the world; (2) details of the weather of the month in the United States; and (3) brief discussions of weather warnings, rivers and floods, and weather and crops. There are illustrative charts. The climatological tables comprise summaries of the weather and excessive precipitation data for about 210 stations in the United States, and summaries of the weather observed at about 30 Canadian stations.

It is hoped that the meteorological data hitherto contributed by numerous independent services will continue as in the past. Our thanks are due especially to the directors and superintendents of the following:

The Meteorological Service of the Dominion of Canada.
The Meteorological Service of Cuba.
The Meteorological Observatory of Belen College, Habana.
The Government Meteorological Office of Jamaica.
The Meteorological Service of the Azores.
The Meteorological Office, London.
The Danish Meteorological Institute.
The Physical Central Observatory, Petrograd.
The Philippine Weather Bureau.

The seismological tables contain, in a form internationally agreed on, the earthquakes recorded on seismographs in North and Central America. Dispatches on earthquakes felt in all parts of the world are published also.

Since it is important to have as the name of the month appearing on the cover of the REVIEW that of the period covered by the weather discussions and tables rather than that of the month of issue, the REVIEW for a given month does not appear until about the end of the second month following.

SUPPLEMENTS containing kite observations and others containing monographs or specialized groups of papers are published from time to time.

NOTES TO CONTRIBUTORS.

Authors are requested to accompany their papers submitted for publication with a brief opening synopsis. When an article deals with more than one subject—as, for example, a method of measurement—some experimental results and a theory, each subject should be summarized in a *separate paragraph*, with a title which clearly describes it.

When illustrations accompany an article submitted for publication in the MONTHLY WEATHER REVIEW, the places where they should appear in the text should be indicated, and legends or titles for them should be inserted just after the end of the article. As far as practicable the illustrations when accompanied by their legends should be self-explanatory—i. e., the data on them should leave no doubt of what they are intended to convey.

SOME WEATHER BUREAU PUBLICATIONS.

As the surplus of MONTHLY WEATHER REVIEW, February, April, June, July, and August, 1919, is exhausted, recipients who do not care to retain their copies will confer a favor by notifying the Chief of Bureau, who will arrange for the return postage.

MONTHLY WEATHER REVIEW

CHARLES F. BROOKS, Editor.

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A STATISTICAL STUDY OF WEATHER FACTORS AFFECTING THE YIELD OF WINTER WHEAT IN OHIO.

By THOMAS ARTHUR BLAIR, Meteorologist.

[Dated Weather Bureau, Salt Lake City, Utah, Dec. 1, 1919.]

SYNOPSIS.

The statistical method is applied to the problem of determining what are the important weather factors affecting the growth of winter wheat in Ohio, and their relative importance. The results are expressed as partial correlation coefficients and in linear regression equations of the form,

$$Y=a+b_1x_1+b_2x_2+b_3x_3+b_4x_4+ \ . \ . \ . \ ,$$

in which the coefficients are evaluated by least square methods.

Because of the difficulty of securing extensive data for other weather elements, it is necessary to deal chiefly with temperature and precipitation values. In general, it is to be expected, because of the relatively large and well-distributed rainfall of Ohio, that temperature variations will have more influence than precipitation variations upon the yield.

For the State as a whole, correlations of monthly weather values with the "condition" reports of the Bureau of Crop Estimates, and with the reported yields, show no very close relationships. The correlations with condition give a general indication that a wet autumn, a warm and dry winter and spring, especially a warm March, and a cool and wet May are the most favorable weather conditions. Yield correlations suggest a warm March and June and a cool and dry May as the only important requisites for a good yield.

In Fulton County in northwestern Ohio, and in three counties in the central part of the State, certain 10-day periods in April, May, and June are found to exert a more effective influence on the yield than all other weather conditions combined, except that in Fulton County the March snowfall is also an important factor. It is weather conditions during these 10-day periods, especially temperature conditions, that largely determine yield. These periods are connected especially with the jointing, heading, and filling stages in the growth of the plant.

INTRODUCTION.

In addition to being one of the oldest of cultivated crops, wheat is probably the most important, as world events of the past few years have sharply emphasized. While the climatic zones in which it can be grown successfully are well recognized and the cultural practices in handling it are pretty firmly established, and though there has grown up a considerable body of traditional or empirical knowledge or assumption concerning the influence of the weather factors, yet the actual effects of various kinds of weather upon the progress and yield of the crop are only very imperfectly known. The following study is an attempt to determine more definitely what are the major weather controls in the growth of winter wheat in Ohio, and their relative importance.

There are two general methods by which such a problem may be attacked. One is the experimental method of planting the grain in plots under more or less controlled conditions. This has certain great advantages, but can practically be carried on only at an agricultural experiment station under a settled and continuous policy for several years. The other plan of attack, and the one employed herein, is the statistical method, in which the actual yields under commercial conditions are compared in historical series with the recorded weather conditions. Where reliable records are available for a considerable period this method seems to offer a valuable field of work, supplementary to and in some respects superior to the experimental method, though it must necessarily omit many details, such as differences of culture, vitality of seed, time of planting, kind and condition of soil, etc., and deal only with averages and large factors. It must overlook entirely minor factors, as well as those which, though they may be of first importance in a particular plot, are not generally applicable over large areas, and for this reason offers, perhaps, a better opportunity of viewing the larger and more general controls.

METHODS OF COMPUTATION.

Two particular methods of computing the relationships between weather and yield have been used in this paper. One is the method of partial correlation coefficients, as developed in the textbooks on the theory of statistics,[1] and as previously exemplified in the MONTHLY WEATHER REVIEW.[2] The other plan has been to develop and evaluate a linear regression equation by means of which the yield is expressed as a function of from three to six weather elements. The general equation is written thus:

$$Y=a+b_1x_1+b_2x_2+b_3x_3+b_4x_4+ \ . \ . \ . \ . \qquad (1)$$

In which Y is the yield; x_1, x_2, x_3, x_4, . . . are the various weather elements, such as mean temperature, total precipitation, percentage of sunshine, expressed numerically; a, b_1, b_2, b_3, b_4 . . . are numerical quantities having a constant value for a given equation, to be determined from the data. The assumptions of this equation are similar to those involved in the correlation calculation, first, that a straight line relation subsists between the yield and the weather (which is doubtful in cases of extreme weather conditions), and, second, that the most important influences have been embodied in the particular equation, or that the influences not included have varied independently of those included.

The solution is by means of normal equations as developed in the theory of least squares. The equation may first be simplified by the elimination of a, as follows: The normal equation for a, obtained by multiplying each of the observation equations by the coefficient of a, in this case unity, and taking their sum, will be of the form

$$\Sigma Y=na+\Sigma b_1x_1+\Sigma b_2x_2+\Sigma b_3x_3+\Sigma b_4x_4+ \ . \ . \ . \ . \qquad (2)$$

from which

$$a=\frac{\Sigma Y}{n}-\frac{\Sigma b_1x_1}{n}-\frac{\Sigma b_2x_2}{n}-\frac{\Sigma b_3x_3}{n}-\frac{\Sigma b_4x_4}{n}- \ . \ . \ . \qquad (3)$$

[1] Yule, Introduction to the Theory of Statistics. [The Computer's Handbook, Section V, Meteorological Office, Great Britain.]

[2] Blair, T. A. Partial Correlation Applied to Dakota Data on Weather and Wheat Yield. MONTHLY WEATHER REVIEW, Feb. 1918, 46: 71-73.

Substituting this value in the original equation gives—

$$Y-\frac{\Sigma Y}{n}=\left(x_1-\frac{\Sigma x_1}{n}\right)b_1+\left(x_2-\frac{\Sigma x_2}{n}\right)b_2+\left(x_3-\frac{\Sigma x_3}{n}\right)b_3+\left(x_4-\frac{\Sigma x_4}{n}\right)b_4+\ldots \quad (4)$$

Now it will be noticed that the expressions, $Y-\frac{\Sigma Y}{n}$, $x-\frac{\Sigma x_1}{n}$, etc., are in each case the differences between the values for the individual years and the average values of the same quantities, that is to say, are the departures from the means. Designating these departures by y, D_1, D_2, D_3, D_4, ..., we have for the final form of the equation [3]

$$y=b_1D_1+b_2D_2+b_3D_3+b_4D_4+\ldots \quad (5)$$

From equation 5 the normal equations become—

$$\Sigma D_1y=b_1\Sigma D^2_1+b_2\Sigma D_1D_2+b_3\Sigma D_1D_3+\ldots$$
$$\Sigma D_2y=b_1\Sigma D_1D_2+b_2\Sigma D^2_2+b_3\Sigma D_2D_3+\ldots$$
$$\Sigma D_3y=b_1\Sigma D_1D_3+b_2\Sigma D_2D_3+b_3\Sigma D^2_3+\ldots$$

It is then necessary to prepare tables of the data used, together with the departures, squares of departures, and products of departures appearing in the normal equations, and then to solve these equations simultaneously for the values of b_1, b_2, b_3, ... The solution is most conveniently performed, especially where the number of equations exceeds three, by writing the required values in the form of determinants, and reducing these by successive steps to the second order before expanding. The mechanical work of solution increases very rapidly of course when the unknowns increase beyond four or five.

Some of the advantages of this method over that of partial correlation coefficients are: The effect of the several factors considered is expressed directly in an equation from which the yield for any year can be calculated. The numerical work can be quickly and absolutely checked by substituting in the normal equations. The accuracy of the solution as a forecasting equation can be expressed mathematically by calculating the "scatter"[4], i. e., the square root of the mean square deviation of the calculated from the recorded yields. On the other hand, an inspection of the equation, without this added labor of calculating the results for individual years, will give no hint of its accuracy, whereas the partial correlation coefficients show at once by the nearness of their approach to unity whether the important factors have been included and their relative importance. In the linear equation the numerical values are the result of the units used, which are variously inches, degrees, percentages, etc., and to obtain the relative importance of the coefficients, b_1, b_2, b_3, ..., the unit must be eliminated by multiplying each by its standard deviation, σ. The values of $b_1\sigma_1$, $b_2\sigma_2$, $b_3\sigma_3$, ... are given in the following discussion, accordingly, for the purpose of showing the relative values of the various factors.

In general, the method of partial correlation has been found most satisfactory and convenient for discovering the important factors and their relative weights, while the regression equation gives a more elegant and complete expression of the final relationships and of their actual value in accounting for the yield. The shortness of the record for statistical purposes combined with the complexity of the factors and the long period during which the plant is exposed to the weather renders it impracticable to make preliminary determinations by such means as dot charts and total correlations of single factors. Such results are unreliable, and in order to reach trustworthy conclusions it is necessary to combine a number of elements in one calculation, and to include those elements showing large correlations, whether obviously related, such as temperature and snowfall of March, or apparently unrelated, as in the case of temperatures or precipitation amounts for different periods.

[3] For this particular form of development I am indebted to a memorandum by Prof. C. F. Marvin, Chief of Bureau.

[4] Moore, H. L. Forecasting the Yield and the Price of Cotton.

GENERAL CONSIDERATIONS.

Winter wheat in Ohio is planted in September and harvested in July, and is therefore subject to the influence of the weather for nine months. It would not be expected *a priori*, therefore, that any one month or short period, or any one series of weather events, unless extremely unusual, would have a predominating influence, but rather that favorable or unfavorable conditions in each of the months between planting and harvest would show in the final yield. This is the common belief, countenanced by the practice of the Bureau of Crop Estimates of issuing estimates of condition as early as December 1. The conclusions of this paper cast doubt upon the truth of this belief and the value of this practice as applied to the early stages of growth.

Ohio has a mean annual precipitation of about 38 inches, very well distributed through the year, each month having a normal precipitation of more than 2.50 inches, but winter wheat is successfully grown in interior California, having a normal annual precipitation of 12 inches, and in central and western Kansas with from 26 to 19 inches. The least annual amount ever recorded in Ohio is 28.46 inches, and the months with less than 1 inch are rare, much less frequent than those with more than 4 inches. It is to be expected, therefore, that in general precipitation in Ohio is quite sufficient for wheat, and there is more likely to be an oversupply than an undersupply of moisture. On the other hand, the snowfall is not heavy, much of the winter precipitation being rain, the ground is not long nor deeply covered, subzero (F.) temperatures are frequent, temperatures are subject to large fluctuations, and rise to high values early in the summer. Hence it is to be expected, perhaps, that the condition and yield will show more relation to temperature than to precipitation, Other factors which may have more or less influence on yield are sunshine, snowfall, snow cover, the extremes of temperature, the frequency and duration of very low or very high temperatures, the distribution of precipitation, the length and severity of droughts, etc. There are innumerable combinations of these factors which may affect the growth of the wheat plant, but the difficulty of securing the data for all these factors over considerable areas and periods, and of expressing them in simple numerical form, are great, if not insurmountable, and for the most part the following study has necessarily been confined to temperatures and precipitation, either as monthly or 10-day means and totals, with a few other factors introduced in some of the equations.

There is another set of contributing influences, not wholly disconnected with the weather, but which require separate treatment, and for which extensive data are not available. This includes injury by hessian fly or other insects, by rust, by severe storms, as of hail, and the loss by storms after the crop is practically made or actually cut. As the injury by hessian fly is largely a function of the date of planting and the weather, and that by rust a function of the condition of the seed and the weather, all factors are to a certain extent included in the weather factors.

AVERAGE CONDITIONS FOR THE STATE.

Because of the length of the growing season and the multiplicity of factors that may be expected to affect the growth of winter wheat, and because of the necessity of keeping the number of terms in the equations small, an attempt was first made to consider the progress of the crop from month to month, or for a few months at a time, rather than for the whole season from planting to harvesting, by utilizing the "condition" reports of the Bureau of Crop Estimates. These reports give the estimated condition of the crop on the first day of December, April, May, and June of each season, and the report of April 1 gives the percentage of the crop abandoned. The "condition," as technically used by the Bureau of Crop Estimates, is expressed as a percentage of the "normal." The "normal" is represented by 100, and is defined as "a condition of perfect healthfulness, unimpaired by drought, hail, insects, or other injurious agencies," and is something better than an average but not a perfect or best possible condition. These condition reports are available for the 26-year series, 1893 to 1918.

The first equation was an attempt to determine the influence of the fall weather upon the growth of the wheat plant by comparing the condition, as reported on December 1, with the temperature, precipitation, and sunshine data of September, October, and November. As an illustration of the method used in this and subsequent calculations, the data, the derived values, and the final equation are given in Table 1 below.

TABLE 1.—*Data for calculation of equation expressing condition of winter wheat in Ohio on Dec. 1.*

1	2	3	4	5	6	7	8	9	10	11	26	27
Year.	Reported condition Dec. 1 (per cent).	Departure.	Temperature, October-November (°F.).	Departure.	Precipitation, September (inches).	Departure.	Precipitation, October-November (inches).	Departure.	Sunshine, October-November (per cent).	Departure.	Calculated condition (per cent).	Y−Y[1] (per cent).
	Y	y	x_1	D_1	x_2	D_2	x_3	D_3	x_4	D_4	Y^1	
1893	92	+4	46	−1	1.6	−1.1	6.3	+1.3	44	−4	89	−3
1894	93	+5	46	−1	3.3	+0.6	4.2	−0.8	54	+6	85	−8
1895	74	−14	44	−3	1.7	−1.0	5.3	+0.3	52	+4	81	+7
1896	101	+13	47	0	5.1	+2.4	3.8	−1.2	46	−2	91	−10
1897	......	......	50	+3	0.8	−1.9	7.2	+2.2	51	+3	......	......
1898	102	+14	46	−1	2.6	−0.1	6.9	+1.9	40	−8	93	−9
1899	83	−5	50	+3	2.7	0	3.8	−1.2	47	−1	89	+6
1900	86	−2	51	+4	1.8	−0.9	6.1	+1.1	48	0	92	+6
1901	75	−13	46	−1	2.9	+0.2	2.2	−2.8	52	+4	79	+4
1902	98	+10	52	+5	4.6	+1.9	4.9	−0.1	42	−6	99	+1
1903	80	−8	46	−1	1.5	−1.2	4.7	−0.3	51	+3	82	+2
1904	76	−12	46	−1	2.0	−0.7	1.9	−3.1	46	−2	79	+3
1905	98	+10	46	−1	2.9	+0.2	6.2	+1.2	46	−2	90	−8
1906	97	+9	47	0	2.9	+0.2	5.8	+0.8	39	−9	93	−4
1907	84	−4	44	−3	3.9	+1.2	4.7	−0.3	52	+4	86	+2
1908	62	−26	48	+1	0.6	−2.1	2.3	−2.7	60	+12	75	+13
1909	95	+7	49	+2	1.8	−0.9	4.8	−0.2	54	+6	86	−9
1910	91	+3	46	−1	4.0	+1.3	6.1	+1.1	44	−4	93	+2
1911	83	−5	46	−1	4.9	+2.2	7.9	+2.9	38	−10	101	+18
1912	95	+7	48	+1	3.1	+0.4	3.5	−1.5	58	+10	84	−11
1913	99	+11	49	+2	2.4	−0.3	6.9	+1.9	41	−7	95	−4
1914	94	+6	50	+3	1.4	−1.3	4.9	−0.1	51	+3	87	−7
1915	85	−3	50	+3	4.5	+1.8	5.1	+0.1	56	+8	93	−8
1916	87	−1	48	+1	2.6	−0.1	4.2	−0.8	61	+13	83	−4
1917	83	−5	43	−4	1.9	−0.8	5.3	+0.3	41	−7	84	+1
Sum	2,113	+1	1,184	+9	67.5	0	125.0	0	1,214	+14	2,109	−20
Mean	88.0	......	47.4	......	2.70	......	5.00	......	48.5	......	87.9	−0.8

(Sunshine percentages are averages of data for Cincinnati, Cleveland, Columbus, and Toledo, Ohio, and Parkersburg, W. Va. Other data are Ohio State means.)

Columns 12 to 25 contain squares and products of departures, from which the following sums are obtained:

$$\Sigma D_1^2 = +131 \qquad \Sigma D_2D_3 = +4.01$$
$$\Sigma D_2^2 = +37.44 \qquad \Sigma D_2D_4 = -52.8$$
$$\Sigma D_3^2 = +58.24 \qquad \Sigma D_3D_4 = -137.2$$
$$\Sigma D_4 = 1{,}048$$
$$\Sigma D_1 y = +128$$
$$\Sigma D_1D_2 = -1.3 \qquad \Sigma D_2 y = +109.2$$
$$\Sigma D_1D_3 = +2.7 \qquad \Sigma D_3 y = +173.6$$
$$\Sigma D_1D_4 = +63 \qquad \Sigma D_4 y = -627$$

Normal equations:

$$128 = 131b_1 - 1.3\,b_2 + 2.7\,b_3 + 63\,b_4$$
$$109.2 = -1.3b_1 + 37.44b_2 + 4.01b_3 - 52.8b_4$$
$$173.6 = 2.7b_1 + 4.01b_2 + 58.24b_3 - 137.2b_4$$
$$-627 = 63\,b_1 - 52.8\,b_2 - 137.2\,b_3 + 1{,}048\,b_4$$

Solving: $b_1 = 1.1$, $b_2 = 2.3$, $b_3 = 2.1$, $b_4 = -0.3$.

Substituting in equation (3): $a = 33.8$.

Substituting in equation (1):

$$Y = 33.8 + 1.1x_1 + 2.3x_2 + 2.1x_3 - 0.3x_4$$

Substituting the values of x_1, x_2, x_3, x_4 for individual years in this equation, we get the calculated condition of December 1 as given in column 26. A comparison of the calculated and reported values shows differences ranging from 1 to 18 per cent, with an average difference, disregarding sign, of 6.3 per cent. The square root of the mean of the squares of the differences, which I have called the scatter, is 7.5, while the actual variability of Y, as expressed by a similar quantity, the standard deviation, is 9.8, showing a considerable improvement over chance results. We seem to have here as nearly as they can be expressed by monthly averages for a whole State the main factors on which the December 1 condition depends. Comparing the values of $b_1\sigma_1$, $b_2\sigma_2$, $b_3\sigma_3$, $b_4\sigma_4$, we would say that the precipitation of October and November is the most important of the four factors, but that all have considerable influence, and would conclude that a wet September, October, and November, the two latter being also warm and cloudy, are the factors favoring a high condition.

Making similar calculations for the change of condition from December 1 to April 1, for the percentage abandoned on April 1, and for the change of condition from May 1 to June 1, we get the results shown in Table 2. It was necessary to omit the change from April 1 to May 1, because the condition figures are vitiated for comparative purposes by the omission of the abandoned areas after April 1. In this table the values in each row are relative to each other, but values from different rows have no relative significance. It will be noted also that values in the third row, expressing the percentage abandoned, should be opposite in sign to those expressing condition.

TABLE 2.—*Relative values of weather factors affecting the condition of winter wheat in Ohio on various dates.*

[Values of $b\sigma$.]

	Condition on Dec. 1.	Change of condition, Dec. 1 to Apr. 1.	Percentage abandoned Apr. 1.	Change of condition, May 1 to June 1.
Temperature (° F.):				
October to November	2.52	......	......	......
October to February	......	......	5.71	......
December to February	......	1.80	......	......
March	......	4.31	−8.21	......
May	......	......	......	−1.5
Precipitation (inches):				
September	2.76	......	......	......
September to November	......	......	−0.34	......
October to November	3.15	......	......	......
December to February	......	−3.99	7.22	......
March	......	−0.65	......	......
May	......	......	......	5.4
Sunshine:				
October to November	−1.95	......	−2.48	......
March	......	0.81	......	......
May	......	......	......	1.4
Snowfall, March (inch)	......	−0.89	......	......
σy	9.8	9.6	12.3	7.6
S	7.5	8.1	9.2	5.8

The actual relation between the computed and recorded yields, as shown by the differences between σy and S, is not very close, but is perhaps sufficient to justify the

use of these equations as preliminary indications of the important factors to be considered. We should say that they indicate, as factors favoring a high condition, (*a*) temperatures above normal from October to March, inclusive, especially in March, and temperatures below normal in May; (*b*) precipitation above normal from September to November, inclusive, below normal from December to March, inclusive, and above again in May. They indicate that the variations in the amount of sunshine in October, November, March, and May, and the amount of snowfall in March, are relatively unimportant factors.

Selecting what appear to be the important factors in the above table, and combining them in one equation for the entire season, and correlating them with the yield instead of the condition, we get the following values for the quantity $b\sigma$:

Temperature (°F.):	
March	1.22
October to February	0.67
Precipitation (inch):	
December to February	−0.42
September to November	−0.35
May	−0.05

It will be noticed that the precipitation of September to November and of May is negative instead of positive as in the preceding table where estimated conditions were being considered. The negative value for May is confirmed and increased in the subsequent calculations. The inconsistency may perhaps be explained on the assumption that a heavy rainfall in May will produce an amount of growth which gives the plant an apparently high condition on June 1, but is not actually conducive to a high yield of seed. In other plants it has been found that a vigorous growth of foliage prevents a heavy yield of seed. The data for this last computation are for the 64-year period, 1855 to 1918, and the results should be more dependable than those for the shorter period, but the value of the derived equation $(Y = -3.0 + 0.27x_1 + 0.26x_2 - 0.15x_3 - 0.19x_4 - 0.04x_5)$ as a forecasting equation is disappointingly small, since S is found to equal 3.42, and σy equals 3.70.

The yield data for this long period show a progressive increase independent of the weather, and to eliminate this secular variation, the next calculation was based on the departures from successive 10-year means, of which the value under consideration was the sixth. The method of partial correlation was used, and factors for April and June introduced, in addition to those above, with the results shown in Table 3.

TABLE 3.—*Partial correlation coefficients. Yield of winter wheat in Ohio correlated with monthly temperature and precipitation data.*

[63 years, 1855 to 1918 (omitting 1900).]

	Temperature (° F.).						Precipitation (inch).	
	October to November.	December to February.	March.	April.	May.	June.	May.	June.
1. (6th order)	+0.07	+0.10	+0.29	....	−0.26	+0.19	−0.16	+0.07
2. (4th order)	....	....	+0.30	−0.01	−0.28	+0.18	−0.10	....

After the process of elimination accomplished by the preceding equations, we may consider that we have here combined all the most important weather factors affecting the yield of winter wheat in Ohio in so far as they can be expressed in values for calendar months. As partial correlation coefficients these are all too small to be of much significance, and show that, at least, some of the most important factors controlling yield have not been included, or are not properly expressed in monthly means and totals. This was confirmed by the calculation of a final equation using the four most important of the above-named factors, which gives a scatter of 3.34, as compared with the standard deviation of 3.70; some slight improvement over the former equation, but of little value. We have then reached the negative conclusion that for the State of Ohio as a whole there are no monthly weather values vitally affecting the yield of winter wheat, but that on the whole a warm March and June and a cool and dry May are favorable. All other temperature and precipitation values may be wholly disregarded.

The failure of the yield to show definite response to monthly values is thought to be due to two principal causes: First, the diversity of conditions and differing stages of growth reached in different parts of the State, giving rise to opposite effects. Second, shorter periods at critical stages of growth may have more important effects than periods of a month, and two such periods occurring in the same month may have opposite effects. Accordingly the next step was to confine the investigation to smaller areas and to 10-day periods.

FULTON COUNTY.

For this purpose, Fulton County, in northwestern Ohio, was first studied, the data being readily available in MONTHLY WEATHER REVIEW, SUPPLEMENT No. 2, for the 29-year period, 1883 to 1912. The results of the preliminary study using monthly data are shown in the accompanying Table 4.

TABLE 4.—*Partial correlation coefficients. Yield of winter wheat in Fulton County correlated with monthly temperature and precipitation data at Wauseon, Ohio.*

[30 years, 1883–1912.]

	Temperature (° F.).						Precipitation, December-February (inch).	Snowfall, March (inch).
	October-November.	December-February.	March.	April.	May.	June 1–15.		
1. (4th order)	−0.11	0.30	0.40	....	−0.30	....	−0.21	....
2. (5th order)	−0.11	0.37	0.37	−0.28	−0.15	....	−0.21	....
3. (6th order)	−0.10	0.37	0.38	−0.29	−0.17	0.11	−0.22	....
4. (6th order)	−0.06	0.42	0.04	−0.06	−0.26	....	−0.10	−0.61

The first three sets of coefficients agree very well with those for the State, showing that the December to February temperatures and the March temperatures should be above normal; the April and May temperatures below normal, and the winter precipitation below normal. But by introducing the snowfall of March, as shown in the fourth row, the influence of the March temperature practically disappears, as does that of the April temperature, and the March snowfall becomes much the most important factor, the only others of importance being the winter temperature and the May temperature. We will return to the consideration of this point after examining the influence of shorter periods during the active growing season.

The average date of ripening of winter wheat at Wauseon, Fulton County, is July 5, and the average date of blossoming is June 9. (MONTHLY WEATHER REVIEW, SUPPLEMENT No. 2). Counting back by 10-

day periods from July 5, nine periods take to April 6, about the beginning of active growth, and one of these periods, June 5 to 14, will have as its fifth day the average date of blossoming, June 9. Using the mean temperatures and the total precipitation for these periods, and omitting other factors for the present, we may briefly summarize the results of numerous calculations in lines 1 to 8, inclusive, of Table 5, expressing the relationships by means of partial correlation coefficients.

TABLE 5.—*Partial correlation coefficients (sixth order). Yield of winter wheat in Fulton County, Ohio, correlated with temperature and precipitation data at Wauseon, Ohio.*

[30 years, 1883-1912.]

	Temperature (° F.).								
	Apr. 6-15. t_1	Apr. 16-25. t_2	Apr. 26-May 5. t_3	May 6-15. t_4	May 16-25. t_5	May 26-June 4. t_6	June 5-14. t_7	June 15-24. t_8	June 25-July 4. t_9
	Tillering.		Jointing.			In boot.	Heading, filling, ripening, blossoming, in milk.		
1			−0.59	0.00		−0.24	+0.23		
2								+0.49	
3					+0.20				
4									+0.01
5									
6		+0.42							
7	−0.05								
8		+0.65	−0.89			−0.21		+0.62	
9									
10		+0.58	−0.62					+0.67	
11									

	Precipitation (inch).								Temperature March (° F.). tm	Snowfall, March (inch). S
	Apr. 16-25. p_2	Apr. 26-May 5. p_3	May 6-15. p_4	May 16-25. p_5	May 26-June 4. p_6	June 5-14. p_7	June 15-24. p_8	June 25-July 4. p_9		
	Tillering.	Jointing.			In boot.	Heading, filling, ripening, blossoming, in milk.				
1			−0.09		−0.33	+0.25				
2		−0.13								
3				+0.09						
4								+0.30		
5							−0.11			
6										
7										
8					−0.24	+0.37		+0.36		
9									+0.30	
10						+0.30		+0.35	+0.03	−0.56
11	−0.26									

After completing the calculation of the seven coefficients given in line 1, the method, it will be observed, was to drop the least important of these, and substitute one or two others, and determine their coefficients of the sixth order, without completing the calculation for the remaining terms, until the final computation in line 8. In this way all the quantities were introduced into a correlation calculation of seven terms, most of which had previously indicated their importance. Hence it is thought that fortuitous relations and those apparent relations resulting from large correlations among the weather factors themselves have been largely eliminated.

Several features of these coefficients should be noted. In the first place, three of those in line 8 are much larger than any in Table 3 or than any in Table 4, except the March snowfall. They are of such magnitude as to leave little doubt of a definite connection with the yield. In the second place, the sudden reversal of sign in adjacent 10-day periods is to be noted, especially that between t_2 and t_3, and between p_6 and p_7. Do these correspond to reality? To test this matter a regression equation was formed including only the three factors, t_2, t_3, and t_8. The resulting equation was

$$Y = 0.53 + 0.14x_2 - 0.51x_3 + 0.52x_8 \qquad (6)$$

in which the yield is made to depend absolutely upon these three temperature values. The resulting scatter is 3.54, while the standard deviation is 4.59, which is 1.3 times the scatter.

A comparison of the reported and calculated yields by individual years is shown in curve A, figure 1. In 16 of the 30 years the difference is 2 bushels or less. The only large differences are in the years 1899, 1900, and 1912, when there were extremely small yields, which in 1899 and 1900 were due to extensive injury by hessian fly. The average difference, disregarding sign, is 2.7, and omitting the three bad years, the average is 2.1. The mean of the reported yields is 15.6 and of the calculated yields is 16.2. We can not doubt that these three 10-day temperature periods have had a marked influence on the yield in Fulton County, and that the first and third periods should be warm, and the second cool. The coefficients for p_6 and p_7, being much smaller, a similar study had not been made for them, but the opposite signs persist in all combinations.

What may be the physical explanation of these facts? Mr. F. A. Welton, of the Ohio Agricultural Experiment Station, has kindly given me the following approximate dates of occurrence of various stages in the growth of winter wheat at Wooster, in northeastern Ohio.

Tillering, April 1 to May 1.
Jointing, April 25 to May 20.
In boot, May 20 to May 28.
Heading, May 28 to June 8.
Blossoming, one or two days after heading.
Filling, June 10 to June 20.
In milk, June 20 to June 30.
Ripening, June 30 to July 12.

Now the record at Wauseon, Fulton County, gives July 5 as the average date of ripening, which corresponds very closely with that given for Wooster, and June 9 as the date of blossoming, which is not more than five days later than at Wooster. Assuming that the earlier dates also show approximately the same difference, we conclude that the period represented by t_2 and t_3, when the sign of the temperature influence changes, is the time when tillering has been completed and jointing begins. For the completion of the spreading process relatively warm April weather is needed, but at the beginning of the rapid growth in height of the plant cool weather is beneficial. The large positive value of t_8 indicates the importance of warm weather during the period of filling. Similarly, the values for p_6 and p_7 indicate that the 10 days preceding heading and blossoming, when the wheat is said to be in the boot, should be dry, but that during the heading and blossoming period rain is beneficial. Finally, the coefficient for p_9 indicates that the yield is increased when there is more than the average rainfall during the 10 days before ripening, when the grain is in the milk stage. In all cases, however, the rainfall coefficients are less important and less conclusive than the temperature coefficients.

Returning now to the consideration of the influence of March temperature and snowfall, we substitute the March temperature in the place of t_6, of line 8, Table 5, and we find a coefficient of +0.30. But there is, as might be expected, a large negative relation between the March temperature and snowfall, expressed by the

total correlation coefficient, −0.60. If now we retain the March temperature in place of t_6 and introduce the March snowfall, instead of p_6 we get the results shown in line 10, Table 5; that is to say, the relation of yield to March temperature practically disappears, but a large negative relation to snowfall appears of nearly equal importance with the temperature relations of April 16 to May 5 and June 15 to 24. Introducing the March snowfall, then, as a fourth factor, we get, instead of equation 6,

$$Y = -9.4 + 0.25t_2 - 0.31t_3 + 0.47t_8 - 0.48s \qquad (7)$$

The resulting scatter is 3.04, as compared with the standard deviation of 4.59, a ratio of 1 to 1.5, showing an improvement in accuracy over equation 6. Curve B of figure 1 gives the comparison by years. The average deviation is 2.3, and 20 of the years show differences of 2 or less. The largest deviation is 7 in the hessian-fly year of 1900, but in the 2 other years of very light yield, 1899 and 1912, for which a large discrepancy was shown in curve A, the addition of the snowfall term results in a close agreement. The average of the reported yields and the calculated yields is exactly the same, 15.6 bushels, indicating that the equation might be used to determine with accuracy the average yield over a series of years, as in a case where weather data were available but yield data lacking.

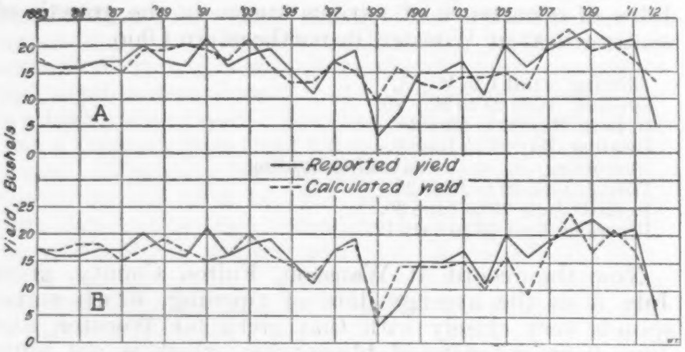

FIG. 1.—Comparison of reported and calculated yield of wheat in Ohio, showing calculated values (B) with and (A) without the snowfall term.

Considering the fact that we are using averages, and are therefore necessarily disregarding the fact that the time of occurrence of those stages that are particularly susceptible to weather influences will differ in different years, and in the same year in different fields, and considering that we are also disregarding unusual and extraneous factors, which are occasionally of large importance, it would seem that we get surprisingly close conformity. A careful application of such an equation to an individual plot, adjusting the temperature periods to the actual growth stages each year, should give interesting and valuable results.

CENTRAL OHIO.

For further and independent study, three counties in central Ohio were selected, namely, Madison, Franklin and Pickaway. The temperature data used are for the Weather Bureau station at Columbus, Franklin County; the precipitation data are the averages for all the stations in the three counties reporting rainfall, the number varying in individual years from 8 to 18; the yield data are the averages for the three counties. To check back with the State data an equation was first evaluated, using the important temperature and precipitation data of autumn, winter, and spring. This gave the following values for $b\sigma$:

Temperature (°F.):	
October–November	0.33
December–February	0.78
March	0.94
Precipitation, December–February (inch)	−0.45

The results agree with the State results, showing the temperature of March as the most important factor, and the temperature of the winter next in importance, but the scatter is 4.43 and the standard deviation is 4.56, showing that these factors are not important in determining yield.

Next, numerous partial correlations were worked out, using the most important of these factors together with the ten-day temperature and precipitation data during the season of active growth. The resulting values are shown in Table 6.

TABLE 6.—*Partial correlation coefficients. Sixth order. Yield of winter wheat in central Ohio correlated with temperature and precipitation.*

[Data for 28 years, 1889-1917 (omitting 1900).]

	Temperature (°F.).								
	Apr. 1-10 t_1	Apr. 11-20 t_2	Apr. 21-30 t_3	May 1-11 t_4	May 12-21 t_5	May 22-31 t_6	June 1-10 t_7	June 11-20 t_8	June 21-30 t_9
	Tillering.		Jointing.		In boot.	Heading, filling, blossoming.		In milk.	Ripening.
1	....	....	....	−0.68	+0.02	−0.58	+0.43	....	....
2	....	....	....	−0.58	....	−0.53	+0.45	0.00	....
3	....	....	....	−0.69	....	−0.67	+0.51	....	....
4	....	....	....	....	....	....	....	....	....
5	....	....	....	....	....	....	....	....	....
6	....	....	....	....	....	....	....	....	....
7	....	....	....	−0.75	....	−0.64	+0.54	....	+0.34
8	....	−0.16	−0.10	−0.72	....	−0.70	+0.54	....	+0.47
9	−0.15	....	....	....	....	....	....	....	....

	Precipitation (inches).						Snow-fall, March (inches).	Temperature (°F.).		
	May 1-11 p_4	May 12-21 p_5	May 22-31 p_6	June 1-10 p_7	June 11-20 p_8	June 21-30 p_9		December to February.	March.	April.
	Jointing.	In boot.	Heading, filling, blossoming.		In milk.	Ripening.				
1	....	....	....	....	....	....	+0.03	−0.19	+0.01	....
2	+0.03	....	....	....	....	....	....	−0.17	....	−0.10
3	....	−0.43	−0.25	....	....	....	+0.02	−0.15	....	....
4	....	....	....	−0.10	....	....	....	....	....	....
5	....	....	....	....	−0.17	....	....	....	....	....
6	....	....	....	....	....	−0.26	....	....	....	....
7	....	−0.49	−0.11	....	....	−0.19	....	....	....	....
8	....	−0.40	....	....	....	....	....	....	....	....
9	....	....	....	....	....	....	....	....	....	....

The insignificance of the December to February and the March temperatures as compared with 10-day temperature and rainfall later in the season is evident from the table, agreeing with the results for Fulton County. In contrast with the Fulton County result, the March snowfall is also unimportant. The average snowfall of this section for March is only 4 inches, with 15 out of 28 years having 2 inches or less, compared with an average fall in Fulton County of 7 inches, with only 5 out of 30 years having 2 inches or less. The unimportance of the snow in the central counties, therefore, is probably due to the small amount that falls and to the fact that it accordingly disappears quickly.

How closely do the important 10-day periods correspond in the two sections of the State? Welton[5] states that the season in central Ohio is from 5 to 7 days earlier than at Wooster, as given above, and we found about 5 days difference between Wooster and Fulton County, hence central Ohio should be from 10 to 12 days earlier than Fulton County. We notice, first, the absence of an important relation during the early jointing stage, but we do find indication of a negative relation in April corresponding, roughly, to t_3 of Table 5, and a very large negative relation during the first decade of May, which is also within the period of jointing. So we have substantial agreement here that during the period of rapid growth in height temperatures should be below normal. For the period of filling, t_8 in Table 5 and t_7 in Table 6, we have exact agreement, temperatures above normal are decidedly favorable. In central Ohio we find also that cool weather is highly important in the preceding period, that of blossoming, while Fulton County fails to show this relation definitely, but there is indication of a negative relation in the period just before blossoming. Warm weather is indicated for the period of ripening in central Ohio, while the corresponding relation is insignificant in the northern county. The two tables agree in showing a negative precipitation relation during the time when the grain is in the boot.

The regression equation embodying the five important factors in line 8, Table 6, is:[a]

$$Y = 29.7 - 0.46x_1 - 0.58x_2 + 0.42x_3 + 0.33x_4 - 1.97x_5 \quad (8)$$

in which x_1 = temperature, May 1-11; x_2 = temperature, May 22-31; x_3 = temperature, June 1-10; x_4 = temperature, June 21-30; x_5 = precipitation, May 12-21.

A comparison of the yields computed from this equation with those reported by the Bureau of Crop Estimates is made in figure 2. The average deviation of the calculated from the reported yield is 2.3 bushels; there is only one difference as great as 5, and 18 of the 28 years

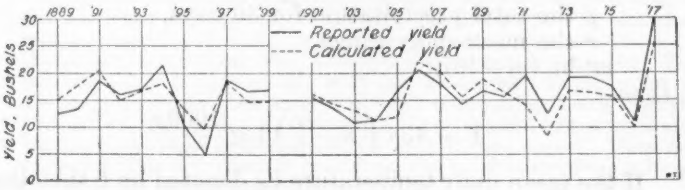

FIG. 2.—Comparison of reported and calculated yield of wheat in Ohio. (Computation from equation 8.)

have differences of 2 or less; the scatter is 2.75, while the standard deviation of the yield is 4.56, which is 1.7 times the scatter. In all but two of the years the change from the previous year is in the same direction for the reported and calculated values, showing the controlling influence of these weather elements, even when the resulting yield is not strictly proportional to them. The average calculated yield for the 28 years is 15.7 bushels, the same as the average of the yields actually reported.

Further to test the soundness of this equation it was applied unchanged to the data for 1918 and 1919, which were not included in the calculation of the equation. The data and calculated values are:

	Temperature (°F.).				Precipitation May 12-21 (inches).	Reported yield (bushels).	Calculated yield (bushels).
	May 1-11.	May 22-31.	June 1-10.	June 21-30.			
1918	62	75	72	69	1.81	18.7	7.1
1919	56	66	76	72	1.12	21.1	19.1

[a] In private letter, quoted above.

It will be noted that for 1919 there is a deviation of but 2 bushels, strongly confirming the value of the equation, while for 1918 the deviation is so great as to cast doubt upon its value. But the season of 1918 was not a normal one. By the 10th of June "wheat was from 10 to 14 days in advance of the normal season" (so stated in National Weather and Crop Bulletin, issued June 11, 1918; also indicated in the issues of June 4 and June 18), due to temperatures much above normal from May 1 to June 10, especially during the period, May 22-31, for which the average temperature, 75°, was 11° above normal. Hence the dates used do not correspond with the stages to which they have been applied, and the extremely high temperatures belong in the third period rather than the second. Advancing the dates, except for the period May 1-10, first, 10 days, and then the later ones 14 days, we have the following values:

Temperature (° F.):	
May 1-11	62
May 12-21	68
May 22-21	75
June 11-20	68
Precipitation, May 1-11 (inch)	0.92
Reputed yield (bushels)	18.7
Calculated yield (bushels)	14.9
Temperature (° F.):	
May 1-11	62
May 8-17	64
May 18-27	72
June 7-16	68
Precipitation, May 1-11 (inch)	0.92
Reported yield (bushels)	18.7
Calculated yield (bushels)	15.0

By this adjustment to the actual growth history the calculated yield is brought within a resonable deviation from the recorded yield, and this abnormal year offers further proof of a direct relation between the yield and the temperature and precipitation values at certain fixed stages in the growth of the plant.

CONCLUSIONS.

1. For the State of Ohio as a whole, a warm March and June and a cool and dry May are favorable conditions for a high yield of winter wheat. All other monthly temperature and precipitation values may be wholly disregarded.

2. There are certain 10-day periods during April, May, and June which appear to be the critical stages in the influence of the weather upon the yield of winter wheat in Ohio. The temperature and precipitation values during these 10-day periods largely determine yield.

3. In northern Ohio, represented by Fulton County, and in central Ohio, the weather should be cool during the jointing stage in the growth of the wheat plant, dry during the development of the boot, and warm while the head is filling.

4. In addition, it should be warm in Fulton County, during the last 10 days of the stooling process. It should be cool in central Ohio during blossoming and warm while the grain is ripening.

5. In Fulton County, and probably also in other counties that are subject to snows of sufficient depth to remain long on the ground, a heavy March snowfall is decidedly detrimental.

6. Because of the large influence of late May and June temperatures, earlier forecasts of yield can be of little value.

It is a pleasure to acknowledge my indebtedness to Prof. Charles F. Marvin, Chief of Bureau, and to Prof. J. Warren Smith for encouragement and suggestion in the prosecution of this study, and to the latter also for the loan of his valuable collection of data for Ohio, which I have used extensively and much of which I would not otherwise have obtained.

RELATION OF THE WEATHER TO THE YIELD OF WHEAT IN MANITOBA.

By A. J. CONNOR.

Dominion Meteorological Office, Toronto.

[Extracts.]

(Monthly Bulletin of Agricultural Statistics, Dominion of Canada, April, 1918, pp. 115-125.)

* * * "The plots [at the various experiment stations] are always as near to the meteorological instruments as is found feasible. Dates of sowing, appearance above ground, stooling, stem roots, heading, flowering, milk-stage, maturity, cutting, are carefully noted, as well as the average height of the plants every seven days.

* * * "Some of the preliminary findings were as follows:

"(1) There appeared to be a relation between the length of the period from sowing to heading, or from the appearance of the plants to heading, and the subsequent yield, the longer periods being positively related to the greater yields.

* * * "It therefore appears that the true explanation of the 'critical period' is as follows. If in the earlier stages of the wheat's growth there be cool and rainy weather, the heading will be delayed and the subsequent yield will be heavy, but if the weather be warm and dry, heading will be hastened and the subsequent yield will be light.

* * * "In regard to rainfall there appears that (1) the effect of the rainfall of the 30 days preceding sowing had, in the long run, no effect upon the subsequent yield; (2) in each of the 30 day periods after sowing, and in all combinations of them, the effect of increased rainfall was to increase the yield, except, perhaps, the fourth; (3) the rainfall of the third 30 days after sowing was the most potent in increasing the yield; (4) that the rainfall effect was cumulative, the correlation coefficient for the 120 days being the largest.

"In regard to mean daily range of temperature there appears (1) that in all the 30-day periods succeeding sowing the coefficient was negative, indicating that the yield was increased by a lowered range; (2) that in the case of the first period after sowing the coefficient is negligible; (3) that in the case of the third period the coefficient is largest, five and one-half times the probable error; (4) that any combination of other periods with the third produces a smaller coefficient than that for the third alone.

"In regard to mean daily minimum temperature, we have that (1) the effect of this factor in the first and fourth periods after sowing is zero; (2) in the second and third periods the coefficient is negative, indicating that the yield is increased by a lowered temperature; (3) in the case of the third 30 days after sowing, the coefficient is greatest; (4) combinations of other periods with the third produce a smaller coefficient.

* * * "From the results so far attained it is not educible that there is a critical period of short duration. The coefficients for the third 30 days after sowing are the largest, but this division into 30-day periods was arbitrarily chosen, and there is nothing to show that a larger or smaller period, if chosen, might not have revealed still larger coefficients. From the two sets of data, together, without more detailed treatment, we may assert, with fair justification, that the first 90 days after sowing are very important with regard to moisture and coolness, but that ordinarily there is sufficient moisture in the soil in the first 60 days for the young plants, and low enough ranges of temperature to prevent evaporation to a harmful extent. During the latter part of the 90-day period, however, there will ordinarily obtain midsummer weather with increased probability of heat and drought, and in this regard the last part of the 90 days after sowing may be said to be a "critical period." If in this "critical" time the weather be warm, dry, with great temperature range, the wheat plants will head early and the harvest will be light, but if the cool and moist conditions continue, heading will be postponed and the yield increased. Now, the average date of sowing of wheat in Manitoba since 1890 is approximately April 25, which will fix the average time of the "critical period" as the last week of June and the first three weeks of July. Hence the variability of early July weather may be regarded as the "critical factor" in wheat production in Manitoba.

* * * "The three variables used were the rainfall, mean daily minimum temperature, and mean daily range of temperature, all for the third 30 days after sowing, and it was found that these are to some extent intercorrelated. The minimum is slightly and the rainfall to a much greater degree correlated with the range, both negatively, while there is no relation between the minimum and the rain. Since the rainfall is related positively and the other factors negatively to the yield of wheat, the quotient $\frac{\text{Rain}}{\text{Range} \times \text{minimum}}$ should be related positively. The plotting of these quotients against the yields led to the following equation:

If Y be the yield in bushels per acre,
m the mean minimum temperature,
p the total precipitation for 30 days,
r the mean daily range,
m^1 be $(m-40)$,

then—

$$Y = .434\left(m - \frac{r}{2}\right)\log\frac{1000p}{rm^1}$$

If the mean daily temperature be denoted by t, then the quantity $\left(m-\frac{r}{2}\right)$ may be written $(t-r)$.[1]

PREDICTING MINIMUM TEMPERATURES.[2]

By J. WARREN SMITH, Meteorologist.

[Weather Bureau, Washington, D. C.]

[Author's abstract.]

A mathematical discussion of the relation between the relative humidity in the late afternoon and the variation of the minimum temperature during the coming night from the afternoon dewpoint temperature, when radiation conditions prevail.

The study shows that there is a well-defined relation which can be expressed by the curve for a parabola. This curve can be constructed by the "star point" method of curve fitting instead of by the more tedious well-known least square method.

[1] It is probable that closer approximation might be obtained by least-square treatment of $(m-40)$, the constant 40 being slightly changed.

[2] Presented before the Philosophical Society of Washington Dec. 20, 1919, and the American Meteorological Society, St. Louis, Dec. 30, 1919. To be published in full in MONTHLY WEATHER REVIEW SUPPLEMENT 16, 1920.

The equation used is written $v=x+by+cz$. In which v is the variation of the minimum temperature from the evening dewpoint; b is the evening relative humidity, and c is the square of the relative humidity; x, y, and z are the three unknowns, which are evaluated from three normal equations which are readily written by the star point method, after the data have been properly charted. The results are remarkably accurate. The studies show that the minimum temperature can be closely predicted in the orchard at considerable distance from the observing station; that the hygrometric observations made at noon may be used quite as well in some instances as those made in the evening, and that the equation will sometimes apply as well to cloudy as to clear nights.

DISCUSSION.

Prof. H. J. Cox remarked that the cranberry marshes of Wisconsin showed extraordinarily low temperatures, considering the high humidities, which condition he ascribed to the shallowness of the moist blanket of air.

Prof. W. J. Humphreys told of a case where, in order to protect his orchard, a farmer had driven his cattle and horses back and forth through the orchard, and the animal heat was sufficient to protect the trees against frost. This has the double advantage of supplying heat at moderate temperature in such a manner that it will not rise quickly above the trees, and of stirring the air.

FORECASTING FROSTS.

By B. A. KEEN.

[Discussed by J. Warren Smith.]

(Nature, Jan. 1, 1920, p. 450.)

The author refers to different methods of frost protection and minimum temperature forecasting. Under frosts the writer says:

Up to the present, no complete correlation has been made of frost in any particular locality and its causes. For this purpose an examination by statistical methods of a series of continuous observations (of the automatic recording type) of meteorological factors is needed. The published papers deal usually with one factor, such as dewpoint or air temperature, and the number of daily observations made is small. This is due, no doubt, to the necessity of keeping the cost of apparatus and working as low as possible for the sake of the growers. However, a general idea of the factors concerned can be obtained from a broad survey of the various papers.

For several seasons the Weather Bureau has been making a careful temperature and frost survey in the citrus district at Pomona, Calif., and the deciduous fruit orchards near Medford, Oreg. Very valuable data have been collected on temperature differences as affected by topography, temperature fluctuations as affected by wind movement, changes in the dewpoint during the night, radiation with and without a smoke or smudge cover, and the temperature at different elevations when orchard heating is going on. A large number of thermometers have been exposed and special long-range thermographs kept in use. The radiation observations have been made with special apparatus used by the Solar Radiation Division of the Bureau. The work is now under the direction of Mr. Floyd D. Young, and the results will soon appear in print (in Farmers' Bulletin 1096).

One important result has been to show that so-called smudges are of small value as compared with the dry-heat method of orchard heating.

In connection with the forecasting problem Mr. Keen refers to a study by Hellman on the effect of an overcast sky on air temperatures near the ground. (Preuss. Akad. Wiss., Berlin, 38, 1918, p. 806); on various methods of predicting the minimum temperatures on radiation nights by Smith (U. S. MONTHLY WEATHER REVIEW 42, 1914, 573; 4, 1917, p. 402) and some observations by Franklin on the cooling of the soil at night, with special reference to late spring frosts. (Proc. Royal. Soc., Edin., 39, 1919, p. 120.)

The credit given J. Warren Smith in originating the median-hour method of predicting minimum temperatures should be only in the application of the idea which was first noticed by the writer in an article by E. A. Beals.

Referring to the study by T. B. Franklin, the writer says:

"As a result of observations of temperatures in the air, on the soil, and at a depth of 4 inches, Franklin concludes that a prediction of frost depends on assessing the value of: (1) Average relative humidity during the night; (2) the temperature of a given depth (4 inches) at the time of surface minimum temperature; (3) the conductivity of the layer between the assigned depth and the surface; and (4) the difference between the surface-soil minimum and that of the air above it. These determinations are necessary because: (1) The radiation from the soil on calm, clear nights is a function of the relative humidity (A. Ångström, Smithsonian Misc. Coll., 65 No. 3); (2) the radiation from the soil can be accounted for in balancing the upward conduction and the latent heat of freezing, the residue only cooling the soil; and (3) the temperature of the surface soil rapidly falls sufficiently below the temperature of the 4-inch depth to make the conduction from this depth balance the radiation; after this the surface temperature falls no faster than that of the 4-inch depth."

WINTER INJURY OF FRUIT TREES.

By JOSEPH ASKAMP.

(Abstracted from Circ. 87, 12 p., illus., Purdue Univ. Agr. Expt. Sta., 1918.)

The severe winter of 1917–18 has caused irreparable damage to thousands of peach and apple orchards in Indiana.[1] The heaviest toll was taken of the peaches, amounting all the way from very slight or no injury to the complete destruction of entire orchard tracts. It seems safe to say that for the State as a whole the damage has cut the bearing acreage of peaches at least 60 per cent. The mortality among young peach trees which had not yet borne fruit was small, however, so that in a short time normal production should be restored.

"A part of the acreage where the injury was severe will probably not be planted again to peaches. This is as it should be, for many of these locations were not well adapted to such a tender fruit. While the trees in many such locations were heretofore able to survive the winters, the buds or blossoms were more commonly killed than in more favorable situations. * * *

* * * "In the case of the apple, the young trees from 3 to 14 years old suffered the greatest injury. * * *

[1] During December and January unusually severe weather prevailed over the greater part of the country east of the Rocky Mountains, especially in the length of time that low temperatures were maintained and the large area involved. The cold weather continued into the first part of February in the northeast.

In Illinois the temperature fell to −23° F. in December and January and to −24° in February. A record of −30° was reached in Indiana in December, −24° in January, and −22° in February. In Ohio the lowest reported was −31° in December and −24° in January and February. The temperature fell to from 40° to 42° below zero F. at a number of places in the plateau districts of New York on December 30, and to below −30° during both January and February. (See MONTHLY WEATHER REVIEW, Dec., 1918, 46: 570–580.)—*J. W. S.*

"Elevation and varieties were among the most important factors in influencing winter injury. A high location proved to be a decided protection for both peaches and apples. * * *

* * * "Other fruits are of relatively minor importance in Indiana and there are only isolated cases from which to draw information. Pears have been injured somewhat more than apples. Sweet cherries were next in tenderness to the peach. Sour cherries suffered no permanent injury, although in one poor location sapwood killing in spots was evident, The plums were not quite so hardy as the apples, except the American varieties, which came through practically uninjured."

"The most severe injury in both the peach and apple originated in the trunk and main branches. This was undoubtedly due to the degree of maturity, as these portions of the tree would be the last to ripen. * * *

"Aside from elevation and variety, the hardiness of the tree was influenced by the growth conditions prevailing during the summer of 1917; that season was short and wet. It is probable that many trees failed to mature their wood properly. Had a normal growing season preceded the severe winter, there might have been no killing in the apple. Thus, even should a like winter come again, unless it were preceded by a similar growing season, the results would not necessarily be duplicated. The chance, therefore, of apples again winter-killing to a similar degree are small."

The balance of the circular is devoted to descriptions of injuries, the best methods of caring for the injured trees, and the insects associated with winter injury.—*J. Warren Smith.*

THE WORK OF THE U. S. WEATHER BUREAU IN THE WEST INDIES.[1]

By OLIVER L. FASSIG, Meteorologist.

[Dated: Weather Bureau, San Juan, P. R., Dec. 1919.]

During the Spanish-American War the presence of a large fleet of our naval vessels in the tropical waters to the south urgently called for special protective measures in the Gulf of Mexico and the Caribbean Sea. In June, 1898, Congress authorized the Weather Bureau to establish and operate weather-reporting stations at selected locations in the islands of the West Indies and along the adjacent coasts of the Caribbean Sea and the Gulf of Mexico.

While the primary object of the new service was the protection of the naval forces of the United States, additional arguments were the greater protection against loss by storm along our own Gulf coast and the coast of the south Atlantic States, as well as the necessity for additional safeguards to the rapidly growing commercial interests in these waters with the opening of the Panama Canal.

Skilled observers of the Weather Bureau were located at 10 well-distributed points within the hurricane area, with instructions to report weather conditions twice daily by cable to Washington from June 1 to November 30, the period during which the severe atmospheric disturbances known as hurricanes may be expected to occur. All reports were cabled to Washington headquarters of the Bureau, where the observations were charted, forecasts were prepared, and warnings issued in case of disturbed conditions arising in any portion of the area.

Soon after our entry into the World War steps were taken by the Chief of the Weather Bureau, Prof. Marvin, to increase the number of storm-warning stations within the hurricane area, and to-day the Weather Bureau has 30 stations on the islands of the West Indies and along the adjacent shores of the Caribbean Sea from which reports are cabled to Washington at 8 a. m. and 8 p. m., Washington time, during the hurricane season, and at which daily records are maintained throughout the year. Within the past year the eastern portion of the area, including the Lesser Antilles and Porto Rico—the gateway to the hurricane belt—has been made a separate forecast district, with San Juan, P. R., as district center.

The system outlined above was inaugurated and maintained primarily as a storm-warning organization, and only incidentally as a climatological service. In the spring of the present year (1919) Prof. Marvin, in view of the growing importance of the commercial and agricultural interests of the area, inaugurated a climatological service, including all of the islands of the West Indies and the adjacent coasts of Central and South America—an area extending from approximately longitude 60 to 90 degrees west, and from latitude 10 to 25 degrees north, or roughly from Barbados, at the extreme east to Panama, and from Curaçao, off the north coast of South America, to Nassau in the Bahama Islands.

Climatological services of large or small extent are maintained in nearly all of the islands of the West Indies under the supervision of their respective local governments, but it is extremely difficult, if not impossible, to get access to the observations made under systems not in accord in methods and measures, or in the absence of regular and systematic publication of results.

Soon after acquiring possession of the Island of Porto Rico as a result of the Spanish-American War in 1898, a climatological service of the Weather Bureau was inaugurated on the Island along lines similar to the climatological sections so familiar to all in the States. This service has been maintained without interruption to the present time, a period of more than 20 years. Records of the weather are made and recorded daily at 60 stations and published monthly.

The first efforts to extend the climatological service to the other islands of the West Indies were initiated during the present year, and arrangements have already been completed to establish 18 stations in our recently acquired Virgin Islands—5 on the Island of St. Thomas, 3 on the Island of St. John, and 10 on the largest and by far the most productive of the islands, St. Croix. Arrangements have also been completed to establish 30 stations in Haiti, with the cordial cooperation of the Haitian Government and officials of the U. S. Navy. From 30 to 40 stations are planned for Santo Domingo.

In the islands referred to above the organizations will be under direct control of the U. S. Weather Bureau. As efficient climatological organizations already exist in Cuba, Jamaica, and the English and French islands of the Lesser Antilles, the plans of the Chief of the Weather Bureau provide for intimate cooperation with the directors of these foreign services with a view to securing a sufficient number of cooperating stations to represent fairly the climatological conditions of their respective islands.

[1] Read at the joint meeting of the American Meteorological Society and the Association of American Geographers, St. Louis, Dec. 31, 1919.

The observations recorded daily will be collected at the end of each month at San Juan, P. R., the headquarters of the new climatological service, and published in a form similar to the climatological section reports being published by the Weather Bureau in each of the States of the Union.

The working out of the details of the organization here outlined will require time, but there is every indication that the cordial cooperation of the foreign Governments concerned will enable the Chief of Bureau to establish, within a year or two, a climatological organization in the tropical area to the south of us which is destined to be of as great value to the agricultural interests of the world as the storm-warning system has proved to be to the shipping and commercial interests in the past 20 years.

Additional plans of the Chief of the Weather Bureau for the tropical organization at San Juan include experiments in upper air conditions in the Tropics to advance our knowledge of the general circulation of the atmosphere and the development of storms within the hurricane belt and to aid in charting aerial routes for the aviator of the future.

AEROLOGICAL WORK IN THE U. S. NAVY.[1]

By Lieut. C. N. KEYSER, U. S. N.

[Author's abstract.]

The Navy has contributed from an early time to the development of meteorology in the United States. The work of Lieut. Maury as early as 1844 is conspicuous as an example of this effort. The development of naval aviation made necessary the training of an Aerological Section, whose value during the war was such as to make its continuation necessary. Its importance as a peace-time activity has been demonstrated in connection with the trans-Atlantic flights and the recruiting trip of the *NC-4* along the coast and up the Mississippi. All of these undertakings were in conjunction with the Weather Bureau, with which the Navy maintains close cooperation. Excellent communication, such as provided by the telegraphic service of the Weather Bureau in conjunction with the radio service of the Navy, has been found of prime importance. The Meteorological Society should prove an excellent medium for cooperation between the Weather Bureau and all other agencies interested in the development of the science of meteorology.

REPORT OF THE CHIEF OF THE WEATHER BUREAU, 1918-19.

The Report of the Chief of the Weather Bureau for the fiscal year ending June 30, 1919, recently published, contains, in addition to the report on the usual and well-known phases of the Bureau's work, certain other interesting material. Occupying a conspicuous place in the report is a discussion of the part the Weather Bureau played in war-time meteorology in such activities as the establishment of aerial wind forecasts, and cooperation with the Army among established established aerological stations; examples of the relation between the work of the Bureau and aeronautics are given in the successful trans-Atlantic flights of the *NC-4* and the British dirigible *R-34*. The "Highways Weather Service," which is a new project, is one of great interest and value, in which the principal Weather Bureau stations keep in touch with the condition of roads and important highways; the service has proved so popular to motorists and others who have frequent use for road information that it has already proved its value. Investigations in volcanology were begun at Kiluea Volcano in Hawaii, with the expectation that they may be extended to volcanoes in Alaska and other portions of the possessions of the United States. Hampered as they were by the war, marine observations are once more being established and extended upon a program which will lead to much more extensive observations over the great ocean areas.—*C. L. M.*

[1] Presented before American Meteorological Society, St. Louis, Mo., Dec. 30, 1919.

REPORT OF THE BRITISH METEOROLOGICAL COMMITTEE.

[Reprinted from *Nature*, London, Jan. 1, 1920, pp. 446-447.]

A report of the Meteorological Committee for the year ended March 31, 1919, has recently been issued. This is the first report since the Armistice, and much interesting information is given in it. Immense strides have been made in meteorology, and the Meteorological Office has expanded accordingly, dependent on the necessities of the war. Whereas the sum available, including many costs for the Services, in the year 1913-14 was 29,380*l.*, in 1918-19 it was 66,371*l.* A much greater demand was made on the office for meteorological instruments, and for forecasts of all descriptions, including the upper air. The marine division, on the other hand, which is dependent for its information on the Royal Navy and mercantile marine, experienced a great falling off in the number of documents received from observers at sea, the documents numbering 2,738 in the year 1913-14 and only 43 in 1918-19. Throughout the war there was great activity in the supply of data to the Army, Navy, and Air Service, and the work commonly undertaken in times of peace was greatly augmented, although most of the information was considered private and was withheld from the general public. The restrictions upon the circulation of meteorological information were removed after the signing of the Armistice. Reports for the several branches of the office show the variety and extended work now undertaken. Any future report will presumably be made through the Air Ministry, to which the Meteorological Office is now responsible.

NEW FORM OF BRITISH DAILY WEATHER REPORT.

Since April 1, 1919, the Daily Weather Report of the Meteorological Office has been issued in three sections. The following is quoted from the official announcement of the change:

I. British Section (B. report). (pp. 4.)
II. International Section (I. report). (pp. 4.)
III. Upper Air Supplement. (p. 2.)

I. The British Section (B. report) is issued daily at noon, in time for circulation by midday post. It contains:

(*a*) Statistics for British stations observing four times a day at 1h., 7h., 13h., and 18h.

(*b*) Statistics for British stations observing twice a day at 7h. and 18h.

(*c*) Particulars of sunshine, etc., reported from health resorts.

(*d*) Weather map for northwest Europe for 7 h. G. M. T. on the scale 1:10,000,000, with inset maps showing the distribution over the British Isles of upper and lower cloud and visibility.

(*e*) A summary of the weather over the British Isles by districts at 7 h.

(*f*) Forecasts for the districts of the British Isles for the 24 hours commencing at 3 p. m., with a "further outlook" if conditions are sufficiently definite.

II. The International Section (I. report) will be issued for the present on the morning of the day following that to which the report refers, in time for circulation with the day's British Section. It contains:

(a) Statistical data for foreign stations.
(b) Weather maps on the scale 1:20,000,000 for 1h., 7h., 13h., and 18h., the maps for 7h. and 18h. covering a wide area.
(c) Particulars of observations from ships received by wireless telegraphy.
(d) Notes on the weather.

III. The Upper Air Supplement is issued daily at noon. It contains:
(a) Maps showing the direction and velocity of the wind at different levels for 13h. and 18h. of the day preceding that of issue, and for 7h. of the day of issue as deduced by observations of pilot balloons and other methods at the office observatories and the meteorological stations of the Air Ministry.
(b) Particulars of upper air temperatures that may have been reported to the office.
(c) Notes on the upper air.

INTERNATIONAL METEOROLOGICAL COMMITTEE MEETING IN LONDON, JULY, 1919.

The British Meteorological Office has published the minutes of the meeting of the International Meteorological Committee which was held in London, July 3 to 9, 1919 (M. O. 237). The American representative at this meeting was Dr. L. A. Bauer, department of terrestrial magnetism, Carnegie Institution, in place of Prof. C. F. Marvin, Chief of the Weather Bureau, who found it impracticable to attend.[1]

The minutes consist not only of the discussions at each meeting and the resolutions adopted to be presented at the conference of meteorologists in Paris early in October, 1919, but also the letter of Sir Napier Shaw calling the meeting, and the appendices containing the reports of subcommittees. Sir Napier, in his opening remarks, stated the purpose of the meeting as follows:

"The business of this meeting will be, therefore, mainly the information of the representatives of the several countries upon the points to which the attention of the cooperating services must be directed." A fair idea of the scope of the discussion may be gathered from the following: Codes for upper air observations, and for barometric tendency, daily synoptic charts of the Atlantic, polar research, cloud observations, sea disturbance, visibility, transmission of observations by radio, instruction in meteorology for wireless operators. It is impossible to give a detailed account of these discussions, which were informal; but there is no doubt that the meeting was highly successful and amply fulfilled its purpose.—*C. L. M.*

INTERNATIONAL METEOROLOGICAL CONFERENCE.

[Reprinted from *Meteorological Office Circular*, Dec. 1, 1919.]

An International Conference of Directors of Meteorological Institutions was held in Paris at the invitation of the French Government from September 30 to October 6. The British Empire was represented by the following: Sir Napier Shaw, Director of the Meteorological Office, Capt. A. J. Bamford (Ceylon), Lieut. Col. Bates (New Zealand), Mr. H. A. Hunt (Commonwealth of Australia), Mr. H. Knox Shaw (Egypt), Mr. C. Stewart (Union of South Africa), Sir Frederick Stupart (Canada), Dr. G. T. Walker (India), Lieut. Grant (Admiralty Meteorological Service). The majority of the allied and neutral countries were represented at the conference, but unfortunately Prof. Marvin, Chief of the Weather Bureau of the United States, and Prof. Nakamura, Director of the Meteorological Service of Japan, were unable to attend and represent their respective countries.

Sir Napier Shaw was elected president of the conference, M. Angot (France), secretary, and M. Palazzo (Italy), Capt. Ryder (Denmark), Prof. Van Everdingen (Holland) and Sir Frederick Stupart (Canada), vice-presidents.

The first task which the conference set itself was the reestablishment of an international organization for securing cooperation on international lines without which much valuable meteorological effort must inevitably run to waste.

The new organization agreed upon is much on the lines of that which existed before the war. It comprises three bodies (1) Conferences of Directors, (2) the International Meteorological Committee, (3) Commissions. The Conferences, to which the director of any independent observatory or service may be invited, are to be convened every 6 years, not 10 years as heretofore. The Conferences nominate an International Meteorological Committee for the purpose of supervising the carrying out of the decisions of the Conference and generally maintaining international intercourse on meteorological matters during the intervals between the conferences. Membership of this Committee is limited to the directors of independent meteorological services.

The number of members, hitherto restricted to a maximum of 17, has been increased to a maximum of 20. The following were elected members of the present Committee: Sir Napier Shaw (Great Britain), Messieurs Palazzo (Italy), Chaves (Portugal), Nakamura (Japan), Angot (France), Maurer (Switzerland), Sir Frederick Stupart (Canada), van Everdingen (Holland), Ryder (Denmark), Walker (India), Marvin (United States), Jaumotte (Belgium), Hesselberg (Norway), Hunt (Australia), Eginitis (Greece). The remaining five places are left to be filled, as the Committee thinks fit, by cooptation.

Commissions are appointed to discuss and report on special subjects. Commissions on the following subjects were called into being by the Conference:

Agricultural meteorology—President, M. Angot.
Weather telegraphy—President, Lieut. Col. Gold.
Marine meteorology—President, M. van Everdingen.
Solar radiation—President, M. Maurer.
Application of meteorology to aerial navigation—M. Sacconey.
Réseau mondial—President, Sir Napier Shaw.
Exploration of the upper atmosphere—M. Bjerknes.
Terrestrial magnetism and atmospheric electricity—M. Angot.
Polar investigation—President, Sir Napier Shaw.

Having settled the general question of procedure, the Conference passed on to the consideration of practical questions. These discussions ranged over a wide field. Among subjects discussed were meteorological units, the hours of observations for telegraphic reports, the codes to be used the arrangements for securing the transmission of the information by wireless, and the extension of the reports to include more detailed information about clouds and visibility.

Upon the opinion of the Conference being desired as to the unit of pressure which should be adopted for the purposes of international stations, the majority gave a vote in favor of the millibar.

[1] A preliminary report on this meeting by Dr. Bauer was published in the MONTHLY WEATHER REVIEW for July, 1919, p. 449.

NOTE ON HIGH FREE-AIR WIND VELOCITIES OBSERVED DECEMBER 16 AND 17, 1919.

By WILLIS RAY GREGG, Meteorologist.

[Dated: Weather Bureau, Washington, Jan. 29, 1920.]

On the morning of December 17, 1919, a remarkably high wind was observed in the free air above Lansing, Mich. This observation was made by the single theodolite method, altitudes being computed from the pilot balloon's rate of ascent by means of the formula $V = 71\left(\frac{l^3}{L^2}\right)^{.208}$, in which—

V = velocity,
l = balloon's free lift,
and L = balloon's total lift.[1]

The balloon was kept in sight 31 minutes, at the end of which time its computed altitude was 7,440 meters, its horizontal distance from the station, 87 kilometers, and its speed, 74 m. p. s., or 166 miles per hour. At the end of the preceding minute the computed wind velocity at an altitude of 7,200 meters was 83 m. p. s., or 186 miles per hour. So far as known, this is the highest wind speed ever observed at altitudes lower than 10 kilometers.[2]

[1] For development and discussion of this formula see Sherry, B. J., and Waterman, A. T. The Military Meteorological Service in the United States During the War. MONTHLY WEATHER REVIEW, April, 1919, p. 218.

[2] Clayton and Fergusson observed cirrus moving at 103 m. p. s. (230 m. p. h.) at an altitude of 11½ kilometers. Annals of the Astronomical Observatory of Harvard College. Vol. XXX, pt. 3, p. 256. A velocity of 83 m. p. s. (186 m. p. h.) *was recorded* on Mount Washington in 1878. MONTHLY WEATHER REVIEW, January, 1878, p. 10 and American Weather, by A. W. Greely, p. 177.

The wind was unusually steady in direction, its variation from northwesterly between 2,500 and 6,500 meters altitude being at no time greater than 5°. Above 6,500 meters it backed to WNW. and below 2,500 meters it was nearly NNW.

There is always some hesitation in accepting as reliable a record of this kind, when obtained with only one theodolite, because a leaky or otherwise defective balloon would gradually assume a lower ascensional rate than that with which it started, with the result that much higher velocities would be indicated than actually existed. In this case, however, there is reason to believe that the record is substantially correct, for the following reasons: First, the afternoon run at the same station showed a similar, though somewhat less rapid, increase in wind velocity with altitude; second, records on the same day and on the previous day at other stations in the northern part of the country give similarly high values in the lower 3 kilometers. Unfortunately, none of these soundings reached as great an altitude as did the one at Lansing. In Table 1 are given the wind directions and velocities as observed at these stations, only those being included in which the balloon was followed to a height of at least 2 kilometers.

TABLE 1.—*Free-air winds observed in the northern part of the United States on Dec. 16 and 17, 1919.*

Stations.	December—	Time (local standard).	Surface.		250		500		1,000		1,500		2,000		2,500		3,000		4,000		5,000		6,000		7,000	
			Direction.	Velocity (m. p. s.).	Direction.	Velocity (m. p. s.).	Direction.	Velocity (m. p. s.).	Direction.	Velocity (m. p. s.).	Direction.	Velocity (m. p. s.).	Direction.	Velocity (m. p. s.).	Direction.	Velocity (m. p. s.).	Direction.	Velocity (m. p. s.).	Direction.	Velocity (m. p. s.).	Direction.	Velocity (m. p. s.).	Direction.	Velocity (m. p. s.).	Direction.	Velocity (m. p. s.).
Lansing, Mich	17	7:20 a. m.	nnw.	2	n.	7	nnw.	8	nnw.	12	nw.	15	nw.	21	nw.	29	nw.	36	nw.	58	nw.	64	nw.	81	wnw.	80
	17	3:12 p. m.	s.	1	sse.	2	s.	1	nw.	3	nnw.	8	nnw.	11	nnw.	15	nw.	25	nw.	40						
Ellendale, N. Dak	[1]16	10:29 a. m.	nne.	6	ne.	8	nne.	7	nnw.	7	nw.	12	nw.	17	nw.	20										
	16	2:30 p. m.	ene.	5	ene.	4	ne.	4	wnw.	10	wnw.	15	wnw.	21	wnw.	25	wnw.	30								
	[1]17	9:27 a. m.	se.	8	sse.	9	s.	11	wsw.	13	wnw.	17	nw.	20												
Fort Omaha, Nebr	17	3:00 p. m.	se.	3	ssw.	4	w.	8	wnw.	14	nw.	15	nw.	21	nw.	24										
Drexel, Nebr	[1]16	10:20 a. m.	wsw.	3	wsw.	6	w.	13	w.	13	wnw.	14	wnw.	17	wnw.	20	wnw.	23								
	[1]16	2:14 p. m.	nw.	2	nw.	9	nw.	12	wnw.	15	wnw.	17	wnw.	19	wnw.	20	wnw.	23								
	[1]16	5:47 p. m.	n.	2	nnw.	10	nw.	15	nw.	21	wnw.	23	wnw.	24	wnw.	27										
	[1]16	9:37 p. m.	nne.	4	nne.	8	n.	11	nnw.	14	nw.	15	wnw.	19	wnw.	24										
	[1]17	5:29 a. m.	se.	5	sse.	7	s.	10	sw.	16	w.	20	w.	23	w.	24										
	[1]17	10:07 a. m.	se.	5	s.	10	ssw.	13	w.	18	wnw.	21	wnw.	25	nw.	25										
	[1]17	2:01 p. m.	sse.	4	ssw.	7	w.	10	wnw.	14	nw.	18	nw.	22	nw.	26										
Madison, Wis	16	3:00 p. m.	nnw.	2	nnw.	5	nnw.	7	wnw.	15	wnw.	25	wnw.	22												
	17	7:11 a. m.	nne.	7	nne.	9	nne.	11	nnw.	12	nw.	20	wnw.	26												
Royal Center, Ind	16	2:01 p. m.	sw.	2	w.	2	w.	6	w.	16	wnw.	23	wnw.	36												
Camp Knox, Ky	17	8:00 a. m.	n.	6	ene.	7	ne.	5	n.	11	nnw.	17	nnw.	22												
Burlington, Vt	17	8:09 a. m.	n.	4	n.	8	nnw.	8	wnw.	7	w.	8	w.	16	w.	19	w.	18								
Aberdeen, Md	16	8:05 a. m.	w.	4	wnw.	6	wnw.	9	wnw.	25	wnw.	25	wnw.	25	wnw.	39										
Washington, D. C	16	8:16 a. m.	nnw.	2	nnw.	7	nw.	11	w.	17	wnw.	23	wnw.	27												
	16	3:09 p. m.	s.	2	ssw.	3	sw.	7	sw.	14	w.	15	wnw.	26												
	17	3:27 p. m.	nw.	7	nw.	6	nw.	6	nw.	11	nw.	20	wnw.	30	wnw.	35										
Fort Monroe, Va	16	8:00 a. m.	wnw.	3	w.	12	w.	12	wnw.	9	nw.	18	nw.	25	wnw.	27	wnw.	19								
	17	7:55 a. m.	w.	6	w.	13	w.	18	wnw.	18	wnw.	22	wnw.	28												
Langley Field, Va	16	8:22 a. m.	wnw.	7	nnw.	11	nnw.	11	nnw.	10	n.	20	nnw.	31	wnw.	33										
	16	2:30 p. m.	sw.	6	wsw.	6	wsw.	8	w.	14	wnw.	24	wnw.	20	wnw.	23										
Leesburg, Ga	16	7:24 a. m.	n.	3	ne.	5	ene.	5	ne.	8	n.	10	n.	9	nnw.	11	nw.	13	wnw.	20	wnw.	31				
	16	3:08 p. m.	0	0	0	0	0	0	nnw.	3	nnw.	9	nw.	10	nw.	10	wnw.	12	wnw.	17	wnw.	26				
	17	7:24 a. m.	w.	2	wnw.	12	wnw.	14	wnw.	16	wnw.	14	w.	12	w.	14	wnw.	17	wnw.	15	nw.	22				
	17	2:53 p. m.	wnw.	7	wnw.	7	wnw.	10	wnw.	10	wnw.	16	wnw.	18	nw.	14										

Altitude (meters) above surface.

[1] From kite flights.

The figures in this table show that, except at and near the earth's surface, a northwesterly to west-northwesterly current prevailed throughout the northern part of the country east of the Rocky Mountains. At nearly all places the wind velocity rapidly increased with altitude, reaching at 7,200 meters above Lansing, as already stated, a value of 83 m. p. s.

An inspection of the weather maps for these two days shows that there was but little surface barometric activity: High pressure was central over the southern States on both days; another high pressure area, central north of Minnesota on the 16th, moved southeastward to the Lake region by the evening of the 17th; pressure was relatively low between these highs and, in addition, a

poorly developed LOW moved from the Upper Lake region eastward and then northeastward to the vicinity of Newfoundland. Figure 1 shows the pressure

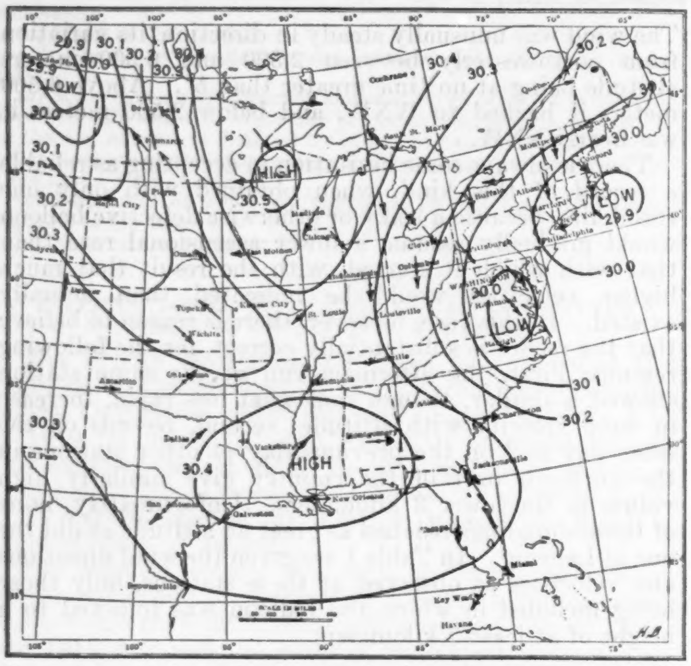

FIG. 1.—Sea-level isobars and surface-wind directions at 8 a. m., 75th meridian time December 17, 1919.

distribution prevailing at 8 a. m., 75th meridian time, December 17, 1919; also, the resulting surface wind directions. These winds ranged in speed from about 2 m. p. s. in the southern States to about 8 or 10 m. p. s. in the northern and middle western States. As indicated in Table 1, the influence of the surface pressure distribution appears not to have extended to a height greater than 1,000 meters above the surface, or less than 1,500 meters above sea level. At all higher levels the trend of the isobars, if parallel or nearly parallel to the winds, was from west-northwest to east-southeast. Further inspection of the weather maps shows that there was a strong south-to-north temperature gradient, unusually cold weather prevailing north of the Lake region, and that the isotherms likewise extended from west-northwest to east-southeast, or parallel in general to the free-air isobars and wind directions. This is well shown in figure 2, in which the solid lines represent surface temperature conditions at 8 a. m., December 17, 1919. The effect of this horizontal temperature gradient was a constantly increasing horizontal pressure gradient as greater altitudes were reached. That this condition actually existed is shown in the kite observations at Ellendale, N. Dak., and Leesburg, Ga. Near the surface there was practically no difference, but at 2,500 meters above sea level the pressure was 18 millibars higher at Leesburg than at Ellendale. The line joining these stations is not at right angles to this pressure gradient, but if we extend the 2,500-meter isobars in a direction parallel to that of the winds at that level, as indicated by the broken lines, figure 2, we find that the distance between those isobars was approximately 900 kilometers, and, if we can still further assume that these are straight isobars, we obtain a gradient wind velocity of about 23 m. p. s., a value differing but little from those given in Table 1 for the 2,500-meter level. At greater altitudes much higher velocities would be expected, not only because of the increasing pressure gradient, but also because of the diminishing air density. Kite records at Ellendale, Drexel, and Leesburg show that at the 2,500-meter level there still persisted a fairly strong temperature gradient from south to north, and it is probable that this increased as higher latitudes were reached, north of the Lake region, for example. The result would be an increasing pressure gradient with altitude, but even if this gradient had remained constant, i. e., the same as at 2,500 meters, the wind would nevertheless have increased, since in the equation for gradient winds the density term occurs in the denominator.

This case and numerous other similar cases bring out clearly the relation between the surface horizontal temperature distribution, in its effect on free-air pressure gradients, and the winds in the middle and upper portions of the troposphere. Surface pressure systems have little influence in this respect, except in so far as they produce modifications in the surface temperature distribution. Naturally, these pressure systems exert a greater or less influence, in proportion as they are well or poorly developed, and during the summer, when latitudinal temperature gradients are weak, they occasionally control the free-air winds to great heights. Thus, easterly winds to a height of 10 kilometers were observed in the southern States during the approach of the West Indian hurricane of September, 1919. During this period "pressure was relatively high over the southern Appalachian region and the interior of the east Gulf States,"[3] and there was little change in temperature from north to south. It has been shown also that in the middle western States cirrus movement from the east is practically never observed except in the summer half of the

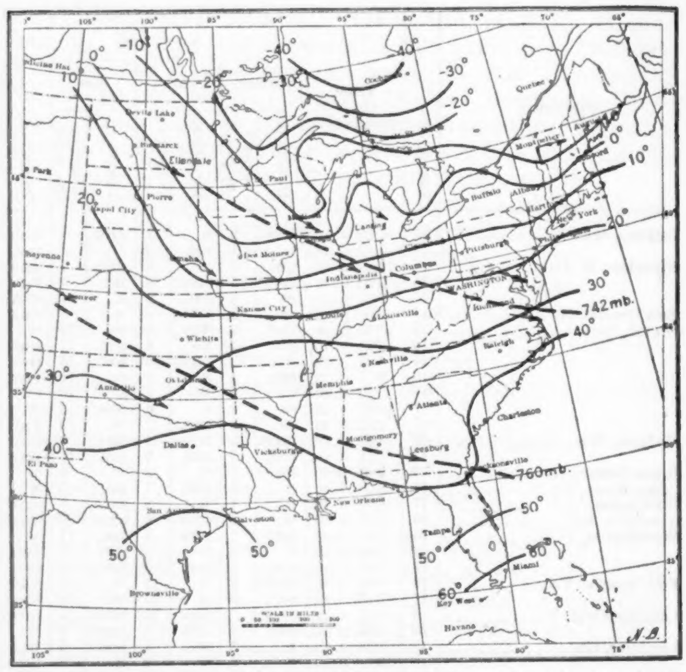

FIG. 2.—Surface isotherms (solid lines), 2,500-meter isobars or instantaneous stream lines (broken lines), and 2,500-meter wind directions (arrows) at 8 a. m., meridian time December 17, 1919.

year when temperature gradients are weak and when moderately high pressure is central northeast of the regions where such movement is noted.[4] Except under abnormal conditions of temperature distribution easterly winds in the higher portions of the troposphere can not occur during the winter half of the year.

[3] For full discussion see "The West India hurricane of September, 1919, in the light of sounding observations." By R. H. Weightman. MONTHLY WEATHER REVIEW, October, 1919, pp. 717-720.

[4] MONTHLY WEATHER REVIEW, October, 1919: The relationship between cirrus movements from easterly points and the occurrence of severe droughts (by George Reeder, pp. 711-715); Easterly movement of cirrus clouds (by L. J. Guthrie, pp. 716-717).

ON CERTAIN CASES OF THE DIMINUTION OF WIND VELOCITY WITH ALTITUDE.

By ALBERT BALDIT.

[Abstracted from Comptes Rendus, Paris Acad., June 16, 1919, pp. 1211–1214.]

In general, winds increase in velocity with altitude, but this is true mainly with the mean of a large number of cases. When the observations are taken separately, however, they can be divided into several groups, and so classified as to bring out certain conditions which persistently produce a diminution of wind speed with altitude. The material for the investigation was obtained from a large number of observations made near Chalons-sur-Marne, from September, 1915, to March, 1918, and in this time there were observed 250 cases where wind speed decreased with altitude. Many of these have been classified as follows:

1. Winds between north and east, from surface to 4,000 meters (67 cases).
2. Winds between east and south, from surface to 4,000 meters (24 cases).
3. Winds between east and south, from surface to 3,000 meters; and then from south to west (13 cases).

The first type occurs with an area of high pressure having its major axis southwest to northeast and centered over the North Sea or Scandinavia. Thus, the measures were made in the southeast quadrant of the anticyclone under fine weather conditions. Under such conditions there is a diminution of the wind velocity at a varying altitude and a backing of the wind with increasing altitude. The second type occurs when the anticyclone covers central Europe and has its major axis directed northwest and southeast. Here the measures are made in the southwest quadrant of the formation. The third type occurs after the passage of an anticyclone which is followed by an important fall of the barometer.

The gradients of pressure required at each height to account for the observed changes of wind are found to be in agreement with those deduced from the surface gradient and the actual distribution of temperature both horizontally and vertically.[1]—*C. L. M.*

[1] This paragraph is from another abstract of the same paper, *Sci. Abs.*, sec. A, Sept 30, 1919, §1160.

THE PREVAILING WINDS OF THE NORTH PACIFIC COAST.

By Professor A. E. CASWELL.

[University of Oregon, Eugene, Oreg.]

[Excerpted from paper read before the American Meteorological Society, New York City, Jan. 3, 1920.]

From a consideration of the planetary circulation of the atmosphere, it appears that in the northern hemisphere the prevailing winds in the region immediately to the south of the center of the 30° high-pressure belt are to be expected to blow from the northwestern quadrant. Similarly, north of the 60° low-pressure belt the prevailing winds are to be expected from the northeastern quadrant, while between these two belts they should be from the southwestern quadrant.[1] * * *

The passage of HIGHS and LOWS will modify the prevailing winds only slightly. * * * Assuming that the LOWS travel due east, which is approximately true in the Pacific Northwest, at points south of the path of a LOW center comparatively cold winds from the southeast may be expected as the storm first approaches. Then soon after precipitation begins the wind will change to the southwest, becoming much warmer. Finally, when the storm center is northeast of the observer, the wind may suddenly change to the northwest or north, accompanied by a rapid fall in temperature, the change being frequently accompanied by rain squalls and followed by clear skies. At points north of the path of the storm center the winds will first blow from the southeast, will then change to east, and, finally, to northeast or north. The preceding statements can readily be applied to cases in which the storm center is not moving due east. This is done by altering the directions mentioned by a suitable amount. Thus: In the northeastern United States the cyclones usually move toward the northeast, hence a counterclockwise rotation through 45° of all the directions just given will bring these statements into fairly good agreement with the facts.

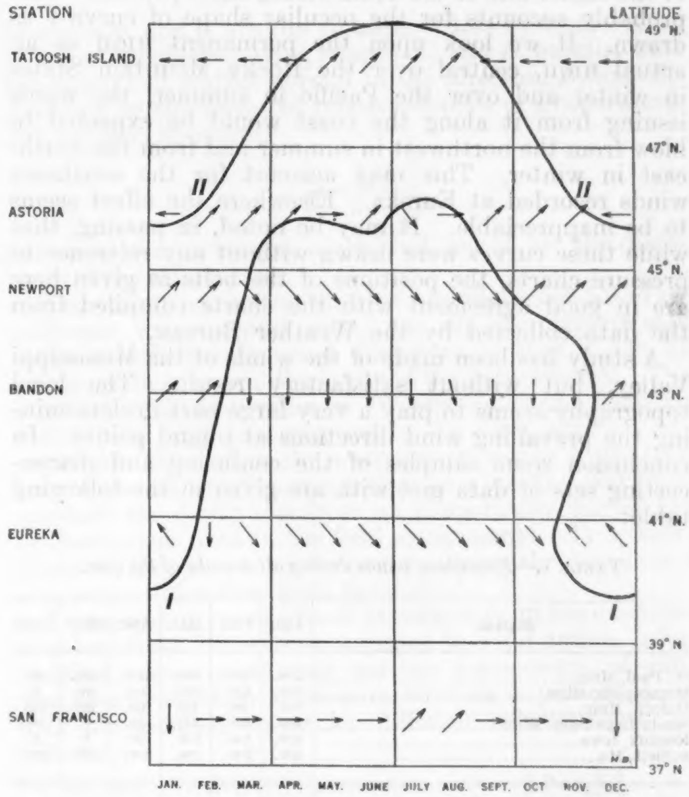

FIG. 1.—Prevailing winds on Pacific Coast.

Local conditions apparently play an important part in determining the directions of the surface winds, so it is generally almost impossible to draw any conclusions from them. An exception is the immediate coast of the Pacific. In figure 1 the prevailing wind directions for every month of the year are given for all the coast stations from Tatoosh Island, three-quarters of a mile west of Cape Flattery, to San Francisco. The data are those given in Henry's Climatology of the United States, 1906, pages 930–989, and cover periods usually considerably in excess of a decade. Taking these stations as a group, the prevailing winds usually blow off the Pacific and should therefore be comparatively free from local disturbances. Curve I separates the months in which the winds usually blow from the northeastern quadrant from those in which winds from the southwest seem to predominate. This curve, therefore, gives the approximate latitude of the center of the high pressure belt where it crosses the shore line at different seasons of the year. Similarly, curve II separates easterly from westerly winds and may be taken as indicating the location of the low pressure belt at different seasons of the year. * * *

[1] Cf. MONTHLY WEATHER REVIEW, April, 1916, 44: 186–196; and June, 1919, 47: 374–390.

Two features of figure 1 require further consideration. The high-pressure belt does not cross the shore line in an east and west direction, but rather from a direction somewhat south of west to north of east. This is due to the presence of the continental HIGH over the United States in winter and to the greater northward movement of the thermal equator over the arid regions of northwestern Mexico and the southwestern States in summer than over the adjoining ocean. In the summer the so-called permanent HIGH is central over the sea, but in winter is central over the land. So in the spring and fall there are periods in which the shift of position is taking place and in which the pressure is fairly uniform over the whole coast. There is, therefore, considerable uncertainty as to the exact location of the center line of the HIGH during these periods. This probably accounts for the peculiar shape of curve I as drawn. If we look upon the permanent HIGH as an actual HIGH, central over the Rocky Mountain States in winter and over the Pacific in summer, the winds issuing from it along the coast would be expected to blow from the northwest in summer and from the southeast in winter. This may account for the southeast winds recorded at Eureka. Elsewhere the effect seems to be inappreciable. It may be noted, in passing, that while these curves were drawn without any reference to pressure charts, the positions of the belts as given here are in good agreement with the charts compiled from the data collected by the Weather Bureau.

A study has been made of the winds of the Mississippi Valley, but without satisfactory results. The local topography seems to play a very large part in determining the prevailing wind directions at inland points. In conclusion some samples of the confusing and disconcerting sets of data met with are given in the following table:

TABLE 1.—*Prevailing winds during all months of the year.*

Station.	Jan.	Feb.	Mar.	Apr.	May	June
St. Paul, Minn	nw.	nw.	nw.	nw.	nw.	se.
Minneapolis, Minn	nw.	nw .	nw.	ne.	ne.	s.
Duluth, Minn	sw.	ne.	ne.	ne.	ne.	ne.
Sandy Lake Dam, Minn	nw.	nw.	nw.	se.	e.	se.
Keokuk, Iowa	nw.	nw.	nw.	se.	s.	s.
Sublett, Mo	nw.	nw.	sw.	sw.	sw.	sw.

Station.	July	Aug.	Sept.	Oct.	Nov.	Dec.
St. Paul, Minn	se.	nw.	se.	se.	se.	nw.
Minneapolis, Minn	s.	s.	s.	s.	nw.	nw.
Duluth, Minn	ne.	ne.	ne.	ne.	sw.	sw.
Sandy Lake Dam, Minn	nw.	nw.	s.	nw.	nw.	nw.
Keokuk, Iowa	s.	s.	s.	nw.	nw.	nw.
Sublett, Mo	sw.	sw.	sw.	sw.	nw.	sw.

Taken in pairs these stations are in practically the same latitude and are not more than fifty or so miles apart in an east and west direction.

DISCUSSION.

Prof. A. J. Henry suggested that in studies of this kind a consideration only of the prevailing wind might show apparent diversities which do not exist. For instance, in the Mississippi Valley, S. winds and NW. winds may blow for about the same number of hours. At one station the NW. may prevail by a narrow margin, while at a neighboring one the S. may prevail. The use of wind roses would eliminate such apparent discrepancies.

SOME DISCUSSIONS OF WIND OBSERVATIONS: DEESA AND KARACHI, INDIA.[1]

By W. A. HARWOOD.

[Abstracted from review by R. De C. Ward, in *Geogr. Rev.*, 1919, 8:281-282.]

These papers are excellent as examples of methods of discussing wind records, in addition to their value as contributions to the local climatology of subtropical northwest India. "The wind roses show very clearly the seasonal variation in wind direction at Deesa [over 200 miles NE. from the Gulf of Cutch] and the prevalence of winds from westerly and southerly points at Karachi [on the Sind coast at the extreme northwestern end of the Indus delta], except in December and January. Many other diagrams are also included."—ED.

[1] A discussion of the anemographic observations recorded at Deesa from January, 1879, to December, 1904. A discussion of the anemographic observations recorded at Karachi from January, 1873, to December, 1894. With an introduction by G. T. Walker. Diagrs. *Memoirs Indian Meteorol. Dept.*, vol. 19, pp. 275-335. Calcutta, 1915.

EVAPORATIVE CAPACITY.[1]

By ROBERT E. HORTON, Consulting Engineer,

[Voorheesville N. Y.]

(Author's abstract.)

The object of this paper is to furnish data showing the relative evaporation rates under standard conditions at different localities throughout the United States. The term "evaporative capacity" is defined by the author as:

"The maximum rate of evaporation which can be produced by a given atmospheric environment from a unit area of wet surface exposed parallel with the wind, the surface having at all times a temperature exactly equal to that of the surrounding air."*

The evaporative capacity at 112 U. S. Weather Bureau stations has been determined from the meteorological normals of temperature, wind velocity, and humidity, by means of the author's evaporation formula. The coefficients in the evaporation formula were determined by experiments covering two years on a standard Weather Bureau evaporation pan. Maps are given showing evaporative capacities for day and night and summer and winter conditions, and tables are given showing monthly evaporative capacities and day and night time temperatures for each of the 112 stations. The application of the maps and data to problems in hydrology, water consumption by plants and agriculture, is discussed.

[1] Presented before the American Meteorological Society, New York, Jan. 3, 1920.
*Cf. MONTHLY WEATHER REVIEW, Nov. 1919, 47:810 (1st col.).

DEVICE FOR OBTAINING MAXIMUM AND MINIMUM WATER SURFACE TEMPERATURES.[1]

By ROBERT E. HORTON, Consulting Engineer.

Figure 1 is a sketch of a wooden float, which I have found very satisfactory for the purpose of obtaining maximum and minimum water surface temperatures in standard Weather Bureau evaporation pans. In taking the readings, the minimum thermometer is simply tilted up on the pivoted support in the usual manner, to set it. The maximum thermometer is held in position on the pivot support by a wire hook marked A.

[1] Presented before the American Meteorological Society, New York, Jan. 3, 1920.

After the reading is taken this hook is lifted, the thermometer taken off from the support and held firmly in hand with the bulb end down, and given one or more sharp rapid downward swings over the evaporation pan, so that any water thrown off goes back into the pan. The same device has been used for the purpose of taking water surface temperatures in lakes and ponds.

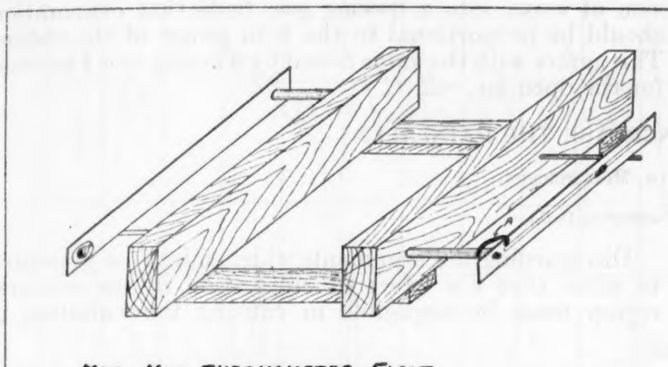

FIG. 1.—Wooden float for obtaining maximum and minimum water-surface temperatures.

In view of the fact that there are so many evaporation records now being kept where records of water surface temperatures, really the most important factor, are omitted, and in further view of the importance of water surface temperature records in lakes and ponds, this note may be of value. Such records are very scarce.

FORM AND AREA FACTORS FOR EVAPORATION.

By W. GALLENKAMP.

(Abstract from Meteorologische Zeitschrift, January-February, 1919, 36:16-22.)

Using small circular atmometer surfaces from 2 to 8 centimeters in diameter, the relative masses of water lost from different sized atmometers were determined. In the first two series of experiments, four atmometers of different sizes were rotated on a frame having arms of 28 centimeters radius. In three subsequent series, atmometers of different diameters were exposed without rotation in the free air. In the sixth series, atmometers of 2.4 and 7.5 centimeters diameter, respectively, were rotated on a frame, one of each size being placed at 14 and one at 28 centimeters radius.

As a result of these experiments the author concludes that—

(1) The mass of evaporation from different sized atmometers subject to wind action increases according to a form of parabolic law with the diameter of the atmometer.

(2) The relative depth of evaporation from atmometers of different sizes subject to wind action varies inversely as about the 0.4 power of the diameters.

(3) The reduction in evaporation depth with increased diameter is practically independent of the wind velocity.

The author concludes that the reduction in evaporation depth with increased area of surface in the wind is due to the carrying forward of vapor from the windward to the leeward side of the atmometer. As a check on this conclusion and on the formula, an experiment was carried out using two atmometers, each 1.5 by 7 centimeters. One of these was placed with its longer axes perpendicular to the wind direction, and the other with its longer axis parallel with the wind. For similar exposures, these two atmometers should give equal depths of evaporation in perfectly still air. When exposed in the wind, the relative depths of evaporation were as 1.80 to 1, the atmometer with its longer axis parallel with the wind giving the smaller result. The author's inverse 0.4 power rule gives a ratio 1.85 to 1 for this case.

The subjoined table shows the relative masses of evaporation (not depths) from atmometers of different sizes, and the corresponding evaporation ratios computed by the author's formula—

$$\frac{V_1}{V_2}=\frac{B_1}{B_2}\sqrt{\frac{L_1^{1.2}}{L_2^{1.2}}}$$

in which v_1 and v_2 are the volumes of loss by evaporation in the atmometers having lengths L_1 and L_2 parallel with the wind, and widths normal to the direction B_1 and B_2. Reduced to the terms of relative depths of evaporation, this formula becomes—

$$\frac{E_1}{E_2}=\frac{d_2^{0.4}}{d_1^{0.4}}$$

for circular atmometers, in which d_1 and d_2 are the diameters of the atmometers.

The author points out that his formula is not based on sufficient experimental data, nor do the experiments cover a sufficient range of diameters so that it can be safely applied beyond the limits of the experiments. The formula would indicate zero evaporation depth from an indefinitely large area exposed to the wind, whereas experiments show that the evaporation depth from very large areas approaches as a minimum a limit not far from one-half the depth lost from an evaporation pan of the ordinary sizes used in the field experiments. It appears probable therefore that the law governing the area factor is exponential rather than parabolic.[1]

The author gives results of experiments on the evaporation loss from atmometers exposed to wind action, using distilled water containing various percentages of salt. The mean reduction in evaporation rate in percentage of that for distilled water for different solutions was as follows:

Per cent salt	1.5	3.0	4.5	6.0
Per cent reduction	8.3	12.0	15.2	18.1

—*R. E. H.*

DISCUSSION.

The experimental work referred to in this paper is not only insufficient, as stated by the author, but perhaps also imperfectly planned. The pans are surprisingly small, and, besides, the turbulence incident to whirling is quite certain to introduce serious irregularities in the rate of evaporation. Nevertheless, the conclusion that the quantity of evaporation is proportional to the 1.6 power of the diameter (for circular vessels) is surprisingly near the theoretical value, 1.5, deduced by Jeffries. (Phil. Mag., 35, p. 273, 1918.)—*W. J. H.*

[1] An exponential formula for area factor which gives results consistent with experience for large areas, derived theoretically from the assumption of stream-line transport of vapor from windward to leeward over an evaporation surface, is given in Engineering News Record, Apr. 27, 1917, pp. 196-199.—*R. E. H.*

ON EVAPORATION FROM A CIRCULAR SURFACE OF A LIQUID.

By H. C. BURGER.

(Reprinted from Science Abstracts, Phys. Sec., Apr. 30, 1919. p. 171. Abs. from K. Akad. Amsterdam, Proc. 21, 3, pp. 271-276, 1919.)

In literature on evaporation the opinion is often expressed or assumed as axiomatic that evaporation from a circular surface is proportional to the area, i. e., to the square of the radius of the surface. Stefan, however, showed that theoretically evaporation by diffusion into a quiescent atmosphere would be proportional to the first power of the radius. Miss Thomas and A. Ferguson [Abs. 71 (1918)] found experimentally that the power of the radius which was necessary to produce the observed results was between 1 and 2. In a dark, very quiet room the power was 1.4; in a lighted room it was 1.5 to 1.6; in the open air it was 1.65.

The author by a mathematical treatment of the diffusion of vapor into a flowing gas, finds that evaporation should be proportional to the 5/3d power of the radius. This agrees with the value found by Thomas and Ferguson for the open air.—*R. C.*

CULTIVATION DOES NOT INCREASE THE RAINFALL.[1]

By J. WARREN SMITH, Meteorologist.

[Weather Bureau: Washington, D. C.]

SYNOPSIS.—Cultivation does not increase the rainfall in the semiarid region. There are well-defined sequences of increasing and decreasing annual rainfall amounts, but there has been no progressive increase or decrease during the past 50 years.

It is not possible to predict the approximate precipitation for any year from past records.

INTRODUCTION.

The land in the Great Plains States is easily cultivated and is naturally very fertile. Wherever sufficient moisture is available, either from rainfall or by irrigation, large crops are possible.

In eastern Texas, Oklahoma, and Kansas, and in southeastern Nebraska, the average annual rainfall is over 30 inches, and it is so well distributed that serious droughts are not of frequent occurrence.

In eastern New Mexico, Colorado, and Wyoming, extreme western Texas, Oklahoma, and Kansas, western Nebraska and South Dakota, central and western North Dakota, and eastern Montana, the average annual rainfall is between 10 and 20 inches and droughts are frequent. In the years of light rainfall, or poor distribution, there is not sufficient moisture for crops unless irrigation is possible. Even in the region where the annual rainfall averages between 20 and 25 inches, crops suffer in the years of light or poorly distributed rainfall. This is particularly true in the southern portion of the Great Plains where the summer temperature is high and evaporation is, consequently, greater than in the northern part. The 20-inch average annual rainfall line follows roughly the 100th meridian of longitude, being considerably west of it in Texas and Oklahoma, slightly west in Kansas and Nebraska, slightly east in South Dakota, and considerably east in North Dakota, as is shown in figure 1.

As a well-distributed rainfall of about 20 inches each year is necessary for crops, unless irrigated, it follows that the western Great Plains is a rather critical region for growing general farm crops. Even when the so-called dry-farming practice is resorted to, crop failures are not unknown.

Years of abundant and well-distributed rainfall encourage a western extension of the cultivated area, and when there is a succession of favorable years farm operations may be pushed so far into the semiarid districts that in ordinary years the rainfall is entirely insufficient for crop needs, and disaster results. During these periods of unusual rainfall, the opinion is frequently expressed that the rainfall is increasing and that this increase must be due to the enlargement of the areas of cultivation.

[1] Presented before a joint meeting of the American Meteorological Society and Association of American Geographers, St. Louis, Mo., Dec. 31, 1919.

Disregarding the arguments which might be presented to show that the effect of cultivation in the semiarid region must be negligible in causing the variation in

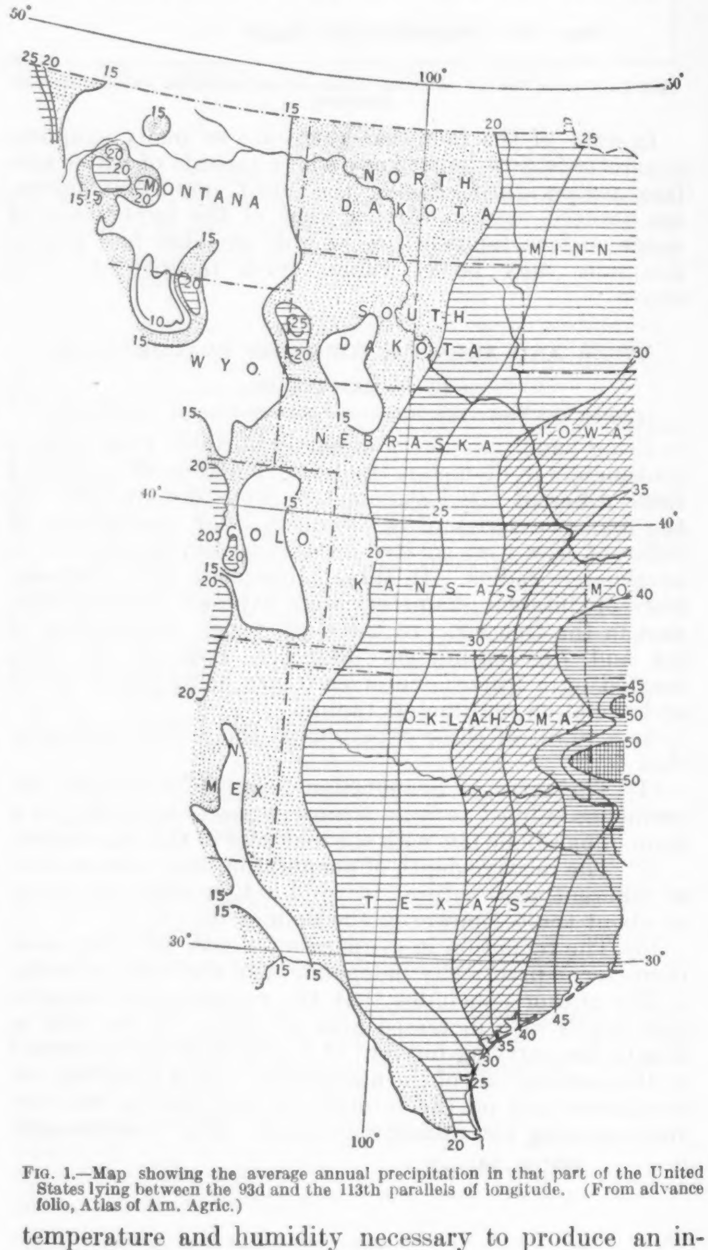

FIG. 1.—Map showing the average annual precipitation in that part of the United States lying between the 93d and the 113th parallels of longitude. (From advance folio, Atlas of Am. Agric.)

temperature and humidity necessary to produce an increase in the amount of rainfall, we have turned our

attention to ascertaining whether there has, or has not, been an increase in the precipitation over the Great Plains. All available rainfall records in that district were collected, tabulated, and charted in the following graphs:

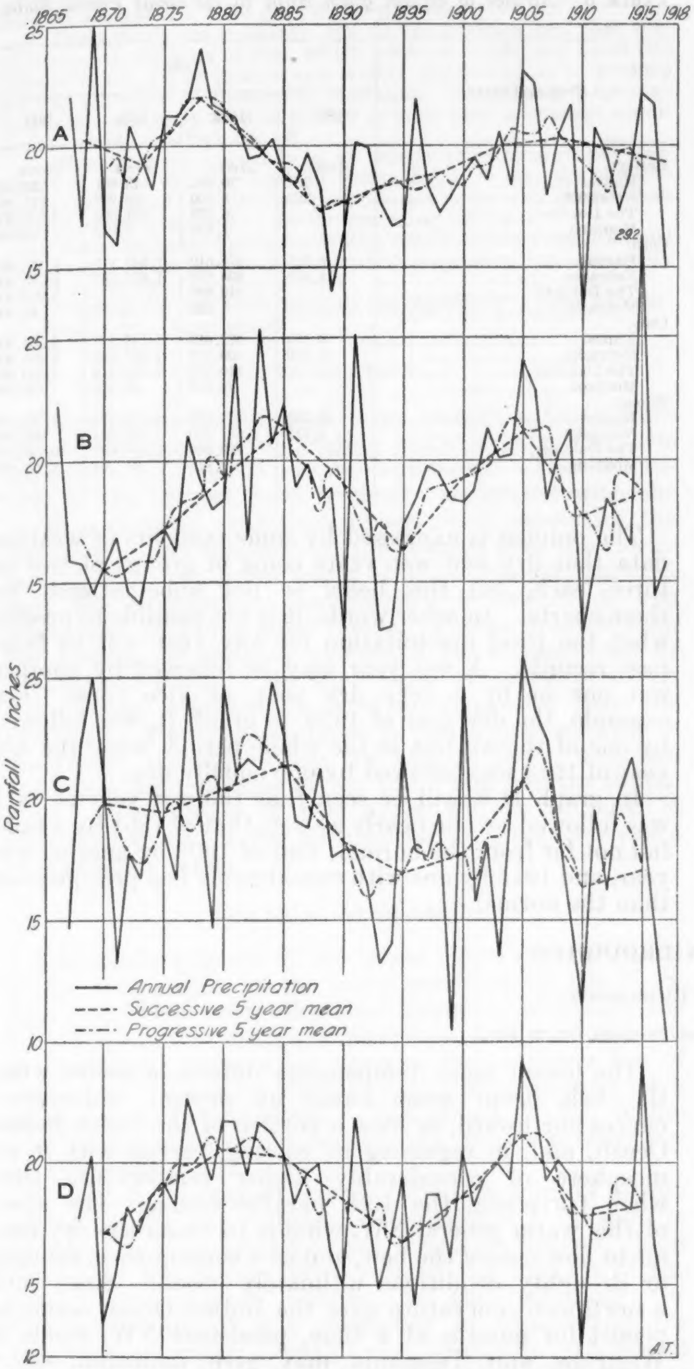

FIG. 2.—Curves showing the average annual precipitation in (A) North Dakota, South Dakota, western Minnesota, central and eastern Montana, and northeastern Wyoming, 43 stations; (B) Nebraska, central and western Kansas, eastern Colorado, and southeastern Wyoming, 38 stations; (C) western Oklahoma and Texas and central and eastern New Mexico, 40 stations; (D) average of the above, 121 stations.

Figure 2 (A) shows curves of the annual rainfall, and the successive and progressive 5-year averages of the annual rainfall from 1867 to 1917, inclusive, for North Dakota, South Dakota, western Minnesota, and central and eastern Montana. Care was taken in this, as well as in the data for the other curves, to keep the stations well balanced between the wetter eastern and drier western parts of the districts.

The curves in A show a rise in the rainfall amounts from the early to the late seventies, followed by a rather sharp decrease to about 1889-90, and then a uniform increase until 1905 and 1906, and after that a moderate decrease.

The average annual rainfall for the first 25 years of this period is 19.6 inches and for the last 25 years 19.4 inches. The average precipitation for each 10 years, beginning with 1868, is shown in Table 1.

TABLE 1.—*Precipitation for each 10 years from 1868 to 1917, inclusive, in the northern Great Plains.*

Period.	Precipitation (inches).
1868–1877	19.8
1878–1887	20.4
1888–1897	18.0
1898–1907	*19.5
1908–1917	19.1

Diagram B gives similar curves for the same period for Nebraska, central and western Kansas, eastern Colorado, and southeastern Wyoming. This indicates a wider variation in the annual rainfall than in the northern States, but the same two crests in the curve. One striking difference between them, however, is that, while in A the first crest was centered in 1877 to 1879, in B it was not reached until about 6 years later. As the second crest comes at about the same time in the two areas, the time between the two crests is 29 years in the northern area and only about 23 years in the central.

The average precipitation for the first 25 years of the period in the Central Great Plains was 18.4 inches, and in the second 18.7 inches. The average for each 10 years is given in Table 2.

TABLE 2.—*Precipitation for each 10 years from 1868 to 1917, inclusive in the central Great Plains.*

Period.	Precipitation (inches).
1868–1877	16.3
1878–1887	20.4
1888–1897	17.6
1898–1907	20.2
1908–1917	18.2

In graph C there are similar curves for the southern Great Plains States, including western Oklahoma and Texas and eastern New Mexico. The first crest in this 50-year curve is at about the same time as in the central division, while the middle depression is slightly later than in either of the others.

The average annual rainfall for the 25 years from 1868 to 1892, inclusive, was 19.8 inches and for the next 25 years only 17.8 inches. The average for each 10 years is shown in Table 3.

TABLE 3.—*Precipitation for each 10 years from 1868 to 1917, inclusive, and for the 12 years from 1852 to 1862 and 1867 in the southern Great Plains.*

Period.	Precipitation (inches).
1852–1862 and 1867 (12 years)	18.8
1868–1877	19.6
1878–1887	20.8
1888–1897	17.5
1898–1907	19.3
1908–1917	16.7

In graph D the data, from which graphs A, B, and C were prepared, were averaged so that this shows the annual and progressive and successive 5-year mean precipitation for the whole western Great Plains region.

This indicates two well-defined crests in rainfall about 25 years apart, with the low part of the curves at the beginning, middle, and end of the period of 50 years.

The average precipitation for the 25 years from 1868 to 1892, inclusive, was 19.2 inches, and from 1893 to 1917, inclusive, 18.4 inches. The average for each 10 years is shown in Table 4.

TABLE 4.—*Precipitation for each 10 years from 1868 to 1917, inclusive, over the western Great Plains.*

Period.	Precipitation (inches).
1868–1877	18.1
1878–1887	20.4
1888–1897	17.5
1898–1907	19.9
1908–1917	18.4

There has been a decided increase in the area unerd cultivation in the Great Plains States during the past 50 years as brought out by figures in Table 5.

If increasing the area under cultivation in any district increased the precipitation, we should expect a steady rise in the annual rainfall amount over the region covered by this study. Instead of finding a regular increase, the graphs in figure 2 make plain that there are well-defined but comparatively short periods of increasing and decreasing rainfall, but which can not be due to cultivation. The crop area is being extended into the drier region because of crop adaptation and better farming methods. Moisture is conserved that formerly ran off, dry-farming methods are being adopted, and crops better adapted to the region are being planted.

An interesting fact in connection with the precipitation records is that dry years occasionally occur during a wet period or wet years in a dry period. This is brought out by the light rainfall in 1882 in graph B, and the very heavy rainfall in 1915 in graph D.

TABLE 5.—*Acreage of certain grain crops in the Great Plains States.*

Crop and State.	Year.			
	1867	1882	1892	1917
Barley:	*Acres.*	*Acres.*	*Acres.*	*Acres.*
Kansas	224	20,882	13,901	750,000
Nebraska	222	156,000	90,223	213,000
The Dakotas		28,273	321,693	2,845,000
Montana		1,852	5,032	90,000
Corn:				
Kansas	6,555	472,619	1,547,175	9,156,000
Nebraska	11,479	400,119	1,615,393	9,240,000
The Dakotas		140,000		3,940,000
Montana		492	1,080	81,000
Oats:				
Kansas	6,555	472,619	1,547,175	2,284,000
Nebraska	11,479	400,119	1,615,393	3,038,000
The Dakotas		140,000	1,174,449	4,500,000
Montana		28,000	66,323	680,000
Wheat:				
Kansas	89,285	1,573,000	4,070,724	3,737,000
Nebraska	9,917	1,657,000	1,253,564	997,000
The Dakotas		720,000	5,410,077	10,716,000
Montana		42,812	41,761	1,727,000

The opinion is expressed by some students of weather data that dry and wet years come in groups of two or three each, but this belief is not substantiated by these charts. In other words, it is not possible to predict what the total precipitation for any year will be from past records. A wet year may be followed by another wet one or by a very dry year, or vice versa. For example, the dry year of 1890, in graph B, was followed by one of the wettest in the whole period, while the dry year of 1913 was followed by one equally dry.

In graph D it will be seen that the wet year of 1877 was followed by one nearly as wet; that of 1891 by a rainfall not far from the normal; that of 1905 by another wet year, and 1915 by one with considerably less precipitation than the normal.

AUSTRALIAN DROUGHTS.

By CHESTER RICHARDSON.

[Dated: Currie, King Island, Tasmania, Oct. 25, 1919.]

Although the primary causes of drought are unknown, an indicator apparently of immediate value is the mean temperature difference for the months June, July, and August, between the southern portion of Australia, and the source from which the latter obtains its rainfall in the months names, viz, the belt of drift weather, which in normal winters extends along a fairly direct line from west to east, in proximity to the 40th parallel of latitude in the Great Southern Ocean. The highest mean temperature difference between the belt and the southern seaboard of Australia obtains in usual winter seasons, when the elements contained in the belt traverse the course above-mentioned. In these conditions, the mean land temperature being higher than that of the belt, the cooler air of the latter shows landwards in convectional circulation to restore equilibrium. The result is SW. winds and rain upon the land.

The lowest mean temperature difference occurs when the belt—from some cause at present unknown—curves northward, or over a portion of the South Indian Ocean, and, in regaining its easting, carries with it atmosphere of considerably higher temperature than when traversing the 40th parallel course. The effect of this warm general NW. wind is to cause the dry land air to flow *toward* the belt, and as a consequence, drought or droughty conditions ultimately ensue.[1] Since such a northward curvature over the Indian Ocean seems to persist for months at a time, persistent NW. winds in Westralia and Tasmania may give indication of a droughty season to follow.

[1] Perhaps associated with the distribution of ocean surface temperatures. Cf. MONTHLY WEATHER REVIEW, November, 1918, **46**: 510–514.

THE DISTRIBUTION OF MAXIMUM FLOODS.[1]

By ALFRED J. HENRY, Meteorologist.

[Weather Bureau, Washington, D. C.]

SYNOPSIS.—(1) The records of both American and European rivers show an average of 7 to 10 great floods per century.

(2) Great floods are primarily due to precipitation, and that precipitation, in the form of rain, which produces floods may be of two distinct types, (a) so intense and widely distributed as to produce flooding regardless of antecedent conditions; (b) moderate rains continued intermittently for 8 to 10 days or more with antecedent conditions favorable to a high run-off.

(3) There does not appear to be an orderly progression in the magnitude of floods with the lapse of years; that is to say, the absolute maximum flood of any 100-year period is not necessarily greater than the absolute maximum flood for the preceding 100 years.

(4) The magnitude of great floods with respect to the average annual flood, seems to increase in a geometrical progression but apparently wholly regardless of the flow of time.

(5) Great floods like great rainfalls are essentially a local phenomenon even for the same stream.

INTRODUCTION.

There is usually for each large stream a fairly well-defined flood season depending quite largely upon the climatic conditions over its watershed. The magnitude of the annual flood is clearly associated with the varying climatic conditions experienced, especially the distribution and intensity of the rainfall over the catchment basin. At times other climatic factors, particularly the temperature distribution, contribute to the magnitude of the annual floods. Floods greater than the average by a fixed amount I have designated as "maximum floods." In the course of years, however, there comes a maximum flood much greater than the average, a flood that is, more or less, epoch making in the region through which the stream flows, and this flood has been designated as the "absolute maximum flood." The object of this paper will be to make a statistical study of the distribution in time and space of maximum floods.

MATERIAL AVAILABLE.

Systematic gagings of the larger rivers of the United States were begun in the early seventies by the U. S. Signal Service (now Weather Bureau), although the U. S. Engineers in charge of river improvements on navigable streams began a few years earlier to gage a few of the larger rivers as an effective aid to improvement work at various points thereon. The object of the Signal Service was different, however, viz, to issue warnings of dangerous floods.

The U. S. Geological Survey began its work of stream gaging in the late eighties and organized a division to oversee the work known as the Irrigation Survey. This branch of the Survey later formed the nucleus of the present Reclamation Service. In the beginning, the Geological Survey was interested in discovering the quantity of water available for irrigation. In recent years it was and is now concerned chiefly in determining the water resources, both surface and underground, in practically all parts of the country. There are, therefore, three of the executive departments of the Government—Agriculture, War, and Interior—directly concerned in the gaging of streams, and one or two others, more or less, indirectly concerned.

The period of continuous observations on this continent is short. On the Mississippi and Ohio it is about 45 years, but for a few places thereon, such as St. Louis, Mo., Cincinnati, Ohio, and Pittsburgh, Pa., as many as 65 years of continuous observations are available. In addition to the above, two New England rivers, the Connecticut at Hartford, Conn., and the Merrimac at Lawrence, Mass., have been gaged for more than half a century. Permanent records of high water were made at Hartford, and these have been referred to the zero of the present gage at that place, hence, a record of the occurrence of floods previous to the beginning of the regular gagings is available for that station and at a few other points throughout the country. The Hartford record, however, is by far the longest, extending as it does over a span of about 300 years.

In the middle Mississippi Valley the record goes back to the 1844 flood, and there is evidence of a previous great flood in 1785, although the level of that flood has never been definitely fixed. Apparently it was in the neighborhood of 42 feet on the present St. Louis gage. The U. S. Engineers, on the authority of the late Dr. Engleman, give it as 42.0 ? feet.

THE CAUSE OF FLOODS.

Broadly speaking, it may be said that the precipitation, having due regard for its intensity, duration, and geographic distribution, is the sole cause of the rise and maintenance of floods of whatever magnitude. There are of course important modifying factors, some of which tend to increase, some to diminish, flood flow; hence, the occurrence of floods of different magnitude for the same season in different years. If the arithmetical mean of the annual floods for a number of years be computed, an expression is obtained which represents the average annual flood. Such an expression has its advantages for the purpose of discussion but is, otherwise, without special significance. The average flood is not necessarily the one which happens with the greatest frequency. When the amount of rain which falls is sufficient to raise ground storage to a high level and thus to saturate the soil, or when a warm spell sets in with rain at a time when a blanket of snow is still on the ground the surface run-off becomes excessive and floods of greater or less magnitude—maximum floods—result. These floods occur irregularly with the lapse of time and the fluctuations of climate. In the course of a few years, or it may be many years, some one of these maximum floods overtops all previously recorded floods, and this flood is known as the absolute maximum for the period in question. Naturally it is of tremendous importance, economically, to determine whether the absolute maximum has been reached and if not what will be its magnitude when it does come.

It can not be too strongly emphasized that the occurrence of the absolute maximum flood is usually conditioned upon the synchronism of certain climatic events which in themselves have no fixed law of occurrence. Very intense rainstorms are seldom long continued and of great extent. The heavy summer showers that occur in the United States being limited in area may cause an extraordinary flood in a small watershed, and doubtless many such floods occur in some part of the country annually. These extreme floods in small streams are completely absorbed as soon as they reach the trunk stream.

[1] Read before the American Meteorological Society at New York, Jan. 3, 1920.

In winter, spring, and early June the occurrence of floods is quite closely related to the quantity of rain which falls; in summer, however, owing to the demands of vegetation and the loss by evaporation, floods are infrequent even with rainfall above the normal. In a typical eastern watershed the run-off may and often does sink to 5 or 6 per cent of the precipitation; hence, it is only when rain is substantially continuous for a day or so that there is any flood menace in summer, except for certain restricted districts to be named in the next paragraph.

North of the 37th parallel the movement of rainstorms in summer is usually too rapid to permit heavy rains on two consecutive days. Under the conditions which prevail in the east Gulf and south Atlantic States, however, a slow-moving cyclonic storm of tropical, or extra-tropical, origin may cause floods in the warm season regardless of the soil and vegetal conditions.

TABLE 1.—*Absolute maximum and average annual flood on 45 rivers of the United States with ratio, absolute maximum to average maximum.*

River.	Station.	Number of years.	Absolute maximum.	Date. Year.	Date. Month.	Mean of annual floods.	Ratio absolute to average.
Atlantic (north).			*Feet.*			*Feet.*	
Connecticut	Hartford	79	29.8	1854	May	20.9	1.43
Merrimac	Lawrence	58	29.7	1896	March	20.2	1.47
Hudson	Albany	30	22.4	1913	....do	15.6	1.44
Delaware	Phillipsburg	25	35.9	1903	October	21.1	1.70
Susquehanna	Wilkes-Barre	22	33.1	1865	March	23.7	1.40
Do	Harrisburg	29	26.8	1889	June	17.2	1.56
Atlantic (south).							
Potomac	Harpers Ferry	28	27.0	1902	March	15.8	1.71
James	Lynchburg	26	33.0	1877	November	13.8	2.39
Roanoke	Weldon	28	60.3	1877	....do	41.2	1.46
Cape Fear	Fayetteville	26	68.7	1908	August	45.2	1.52
Great Pedee	Cheraw	27	44.3	1908	....do	33.9	1.31
Cat-Wateree	Camden	27	40.4	1916	July	30.7	1.31
Congaree	Columbia	24	35.8	1908	August	20.7	1.73
Savannah	Augusta	43	38.8	1908	....do	30.9	1.26
Oconee	Milledgeville	15	33.8	1912	March	24.3	1.39
Ocmulgee	Macon	20	24.0	1887	....do	20.0	1.20
East Gulf.							
Flint	Albany	26	32.4	1897	March	21.8	1.49
Chattahoochee	Eufala	26	56.0	1902	....do	39.2	1.43
Alabama	Montgomery	28	59.7	1886	April	40.7	1.47
Tombigbee	Demopolis	26	72.9	1900	....do	54.9	1.33
Black Warrior	Tuscaloosa	28	66.3	1916	July	52.6	1.26
Pascagoula	Merrill	14	27.0	1916	....do	21.5	1.26
Pearl	Columbia	14	27.6	1909	June	21.1	1.31
West Gulf.							
Trinity	Riverside	16	49.7	1908	June	31.3	1.59
Brazos	Waco	19	39.7	1913	December	22.9	1.73
Colorado	Austin	16	34.7	1900	April	14.0	2.48
Guadalupe	Gonzales	15	38.1	1913	December	20.3	1.88
Interior.							
Ohio	Pittsburgh	65	35.5	1907	March	23.8	1.49
	Cincinnati	58	71.1	1884	February	45.1	1.58
	Louisville	46	46.5	1884	....do	27.8	1.67
	Evansville	46	48.4	1913	March	40.6	1.19
Tennessee	Chattanooga	43	58.6	1867	....do	33.9	1.73
Cumberland	Nashville	45	55.3	1882	January	40.8	1.36
Illinois	Peoria	36	27.1	1849		17.7	1.53
Wisconsin	Wausau	9	15.3	1912	July	8.8	1.74
Mississippi	St. Paul	45	19.7	1881	April	11.0	1.79
	La Crosse	46	16.2	1880	June	10.5	1.54
	Dubuque	44	21.7	1880	....do	13.8	1.57
	Davenport	45	19.4	1892	....do	12.3	1.58
	Keokuk	51	19.6	1888	May	14.0	1.40
	Hannibal	40	22.5	1903	June	17.5	1.29
	St. Louis	72	38.0	1844	....do	27.2	1.40
Missouri	Omaha	44	23.8	1881	April	16.0	1.49
	Kansas City	46	38.0	1844	June	21.1	1.80
Arkansas	Little Rock	47	32.6	1844	May	22.2	1.47
Ouachita	Camden	33	46.0	1882	....do	35.7	1.29
Red	Fulton	33	34.8	1882	....do	28.5	1.22
	Shreveport	36	45.7	1882	....do	34.0	1.34
Pacific Coast.							
Columbia	Umatilla	36	34.5	1894	June	21.4	1.61
Snake	Lewiston	25	26.6	1894	....do	15.9	1.67
Willamette	Albany	27	31.3	1903	January	15.6	2.01
Sacramento	Sacramento	26	29.6	1909	....do	24.8	1.19
American	Folsom	21	38.3	1862	....do	17.7	2.16
San Joaquin	Firebaugh	12	13.7	1911	June	10.6	1.29
Colorado	Yuma	12	33.2	1891	February	27.7	1.20
Grand	Grand Junction	11	13.0	1917	June	10.2	1.27
Green	Elgin	12	17.5	1917	....do	12.6	1.39

MEAN ANNUAL FLOOD.

The mean annual flood on 45 rivers in the United States, using the single greatest flood when two or more floods occurred in the same year, has been computed and the results are presented in Table 1. The average length of record is, for rivers of the north Atlantic drainage, 40 years; south Atlantic, 26 years; east Gulf, 23 years; west Gulf, 19 years; Mississippi, 49 years; Ohio, 54 years; Tennessee and Cumberland, 44 years; Missouri, 45 years; Arkansas, Red, and Ouachita, 39 years; Columbia, 36 years; Colorado, 12 years; and California Rivers, 20 years.

The table shows the name of the river, the gaging point, the number of years of observations, the absolute maximum flood, the year and month of occurrence, the mean annual flood and the ratio of the absolute maximum to the average annual flood. Mr. Weston E. Fuller, in his comprehensive paper, Flood Flows[2] computes the ratio of the maximum flood and the 24-hour average rate of flow as determined by discharge measurements for both the maximum and the average annual flood. Inasmuch as discharge measurements, especially for flood flows, are available for but a very short period, this method was not available. Gage heights, as a rule, indicate with sufficient accuracy the relative magnitudes of the recorded floods. There are a very few cases when changes in the cross section of the stream at the gaging point vitiates the results but none such have been used in this discussion. In the Mississippi below Cairo the channel capacity has been altered to such an extent by the building of levees that no method of comparison for different periods is satisfactory.

The usefulness of the ratio absolute maximum to average annual flood may be determined by comparing the results for streams in different parts of the country. While the ratios in the table speak for themselves, I may be permitted to make the following comment:

The agreement in general is better than was expected. It is a reasonable and fairly accurate inference, except in some cases that will be mentioned later, that the absolute maximum flood will be 1.3 to 1.4 or 1.5 times the mean annual flood.

In the group of New England rivers, including two of the longest records available, the ratio is in substantial accord. The only discordant ratio is that for the Delaware River at Phillipsburg. The ratio in this case is 1.70—that is, the absolute maximum flood was 170 per cent of the average annual flood. Other individual cases of a high ratio in other parts of the country are those for the Potomac, James, Congaree, Colorado and other rivers of Texas, the Wisconsin, upper Mississippi, the Missouri at Kansas City, the Willamette of Oregon, and the American of California. It is convenient to consider all of these cases together. The absolute maximum flood on the Delaware occurred in October, 1903, when, owing to heavy rains over the watershed, the river reached the highest stage for upward of 100 years. The average annual flood on the Delaware is relatively low, due to a succession of years of deficient precipitation. It is believed that more observations will materially change the ratio which now obtains. The high ratios which obtain on the Potomac and James are probably due to natural causes. The run-off of both watersheds in unison with the precipitation fluctuates very widely in different years. As a result of light rainfall the average annual flood has a low value. An intense rainstorm, however, owing to the mountainous character of the upper watersheds of both

[2] Transactions American Society of Civil Engineers, **77**: 564.

rivers produces a rapid concentration of the run-off and a high flood peak. And since an extraordinary rainfall may occur even in a period of deficient precipitation, a single great rainfall will unduly increase the ratio. The high ratio for the Congaree at Columbia, S. C., is not understood. Since it is not supported by the record of other streams in South Carolina and Georgia, an explanation may be sought in the local conditions at the gaging point—probably by the dam below the gage. The high ratio for Texas rivers, especially the Colorado, is doubtless to be attributed to the climatic features of the State by reason of which the variation in the run-off varies widely from year to year.

The unusually high ratios for the Tennessee at Chattanooga and the Missouri at Kansas City are due in part to the use of an absolute maximum flood which occurred some years prior to the beginning of regular observations. The Tennessee at Chattanooga varies from year to year within rather wide limits as will be shown elsewhere in this paper.

The absolute maximum flood in the Missouri at Kansas City occurred in 1844, and the stage then attained was 3 feet above the highest stage within the period of regular observations. The Kansas River, which joins the Missouri at Kansas City, is a stream of variable flow. It seems probable that the high ratio at Kansas City is due to natural causes coupled with an unusually high absolute flood in 1844.

A high ratio appears for the Wisconsin River at Wausau with only eight years observation, and it is to be noted that the absolute maximum flood at this station was a rain flood in July. Further observations for this station are needed.

The Columbia River presents a case of extremely high water in 1894.[3] At Cascade Locks the previous record of high water was exceeded by 6 feet. As the annual flood of the Columbia is essentially a snow flood, an unusual depth of snow combined with high temperature in the melting season may produce large variations in the annual flood on this river.

As might be expected, small ratios obtain at points along the stream where overflow takes place and the cross section of the stream is greatly increased. Evansville on the Ohio, with a ratio of 1.19, and Hannibal, Mo., on the Mississippi, with a ratio of 1.29, are cases in point.

Eleven of the greatest annual floods on eight of the rivers of the United States having records exceeding 40 consecutive years in length have been classed in the order of magnitude from the absolute maximum down to No. 11 in descending scale, and the ratio of each of the 11 great floods to the average annual flood has been computed and is given in Table 2. The standard deviation for each of the 10 stations has also been computed according to the method of least squares and is given in the table at the top of the column.

The uniformity of the ratios in this table is significant. It is obvious that while there is a general similarity in the ratios for all streams, each has its own individuality conditioned in some measure upon the channel capacity at the gaging point and the variability of the stream. Another interesting point brought out by the table is the small difference between the absolute maximum flood and the flood second in magnitude. In no case is the difference more than a few per cent except on the Missouri at Kansas City, Tennessee at Chattanooga, the Mississippi, at St. Louis, and in a lesser degree the Cumberland at Nashville. As before remarked, the absolute maximum flood at Kansas City, Chattanooga, and St. Louis occurred some years prior to the beginning of regular observations. It may well be that these relatively high ratios approximate the true ratio for periods exceeding a century better than do the others.

TABLE 2.—*Ratios of the 11 great floods to the average flood at the gaging stations named; floods arranged in the order of their magnitude from No. 1 to 11, from records of 40 years and upward.*

[Standard deviation in feet and hundredths at top of each column.]

No. of flood.	River.										Mear.
	Connecticut, at Hartford.	Merrimac, at Lawrence.	Savannah, at Augusta.	Missouri, at Kansas City.	Arkansas, at Little Rock.	Ohio, at Pittsburgh.	Mississippi, at St. Louis.	Cumberland, at Nashville.	Ohio, at Cincinnati.	Tennessee, at Chattanooga.	
	3.69	3.73	3.76	4.13	4.28	4.33	4.58	6.79	7.78	9.26	
1	1.43	1.47	1.27	1.80	1.46	1.46	1.52	1.36	1.37	1.73	1.48
2	1.37	1.43	1.27	1.66	1.28	1.37	1.40	1.24	1.35	1.59	1.39
3	1.30	1.38	1.20	1.43	1.27	1.33	1.32	1.22	1.28	1.54	1.32
4	1.28	1.33	1.16	1.37	1.27	1.29	1.30	1.21	1.26	1.41	1.28
5	1.27	1.31	1.15	1.28	1.25	1.29	1.28	1.21	1.19	1.26	1.24
6	1.26	1.25	1.15	1.27	1.25	1.28	1.28	1.21	1.19	1.25	1.23
7	1.26	1.21	1.14	1.26	1.23	1.26	1.24	1.21	1.18	1.25	1.22
8	1.26	1.20	1.13	1.19	1.22	1.23	1.24	1.19	1.15	1.20	1.20
9	1.23	1.20	1.09	1.18	1.21	1.23	1.21	1.19	1.14	1.20	1.18
10	1.23	1.19	1.08	1.13	1.19	1.21	1.19	1.14	1.13	1.19	1.16
11	1.22	1.16	1.07	1.12	1.18	1.20	1.18	1.14	1.11	1.18	1.15

GREAT FLOODS IN THE UNITED STATES WITHIN HISTORIC TIMES.

The record of great floods in this country covers about 300 years in New England, somewhat less in the Middle Atlantic States, about 125 years in the Mississippi Valley and about 70 years in California.

The greatest flood of record in California occurred on the American River at Folsom City on January 8, 1862. The crest of this flood has been definitely fixed at 38.3 feet on the present gage at Folsom City, 8.3 feet higher than any subsequent record.

The greatest flood in the lower Missouri and the middle Mississippi Valley occurred in June, 1844, and the crest of that flood at Kansas City and St. Louis, Mo., was 3.0 and 3.4 feet, respectively, above the highest water since recorded. The 1844 flood seems to have been confined to the western tributaries of the Mississippi south of the Missouri, since its volume alone was not sufficient to cause more than a moderate flood in the Mississippi below St. Louis, Mo.

Six great floods, of over 60 feet on the Cincinnati gage, occurred on the Ohio during the nineteenth century, viz, in 1832, 1847, 1883, 1884, 1897, and 1898. The average interval is 16 years, but there were two intervals of more than double the average and two floods in successive years.

At Pittsburgh two great floods of almost equal magnitude occurred within the nineteenth century, viz, those of February, 1832, and March, 1897, the latter being a shade the higher. It was, however, more or less local to the vicinity of Pittsburgh and flattened out as it passed downstream.

In New England, the greatest flood of record occurred on the Connecticut in 1854 and on the Merrimac in 1896. The last-named was also more or less local to that river; the synchronous flood in the Connecticut was only No. 4 in magnitude.

[3] MONTHLY WEATHER REVIEW, 22:510.

There were 11 great floods in the Connecticut—25.7 feet and over on the Hartford gage—during the Nineteenth century, viz, in 1801, 1807, 1827, 1841, 1843, 1854, 1859, 1862, 1869, 1895, and 1896. The average interval is nine years and the distribution is more uniform than in the Ohio. It is noteworthy as indicating the localization of great floods that in no single year were the great floods concurrent on both the Ohio and the Connecticut.

There were 14 great floods in the Mississippi at St. Louis during the nineteenth century, 32.0 feet or over, as follows: 1811, 1823, 1826, 1828, 1844, 1845, 1851, 1855, 1858 1876, 1881, 1882, 1883, and 1892. The average interval is seven years.

Among the early floods of the nineteenth century that have thus far not been surpassed are the 1862 floods in California, the 1844 floods in Kansas, Missouri, Illinois, and Arkansas, the 1850–51 floods in the Mississippi above St. Louis, and the 1867 flood in the Tennessee above Decatur, Ala.

An examination of the sequence of flood years gives no indication of the existence of a cycle in which great floods are repeated, but shows conclusively, I think, that the dominating control is rainfall, and since there may be one, two, ot even three years of excessive rainfall, it follows that great floods may likewise occur in successive years. The floods of the nineteenth century appear to be grouped in the forties, sixties, eighties and nineties. The single years of great flood in one part of the country or another were 1801, 1807, 1810, 1811, 1814, 1823, 1824, 1826, 1828, 1832, 1838, 1839, 1841, 1843, 1844, 1845, 1846, 1851, 1855, 1858, 1862, 1865, 1869, 1876, 1877, 1878, 1880, 1881, 1882, 1883, 1884, 1886, 1889, 1891, 1892, 1894, 1897. It is probable that for the first half of the century the list is incomplete. The list contains 37 years, but the interval between the years is not uniform. There seems to have been a minimum of flooding in the fifties, except in the Mississippi Valley, widespread floods in the sixties, another decline in the seventies, and the principal maximum of the century in the eighties.

The 1903 floods in Kansas and Missouri covered substantially the same region, although one less in geographic extent than the 1844 flood. The crests reached in the later flood fell about 3 feet short of the 1844 flood, but it seems clear that the meteorological conditions were very nearly repeated after the lapse of 59 years.

The 1915 floods[4] in the same districts come under the same category as those first named. There have been, therefore, a recurrence within historic times of substantially the same rain producing floods in the Kansas-lower Missouri watershed at two intervals of 59 and 12 years respectively.

The meteorological conditions associated with the greatest flood on the Connecticut can be inferred quite accurately from the weather notes that have been preserved. It is quite probable that an area of high pressure and unseasonably low temperature moved into the St. Lawrence Valley and northern New England immediately preceding the rains, and that a weak cyclonic system persisted for several days over, say, the mouth of the Hudson. The relative position of the HIGH and the LOW would give southeast winds and rain over Connecticut and snow over the upper portion of the watershed. Maximum temperatures of 80 degrees were recorded on three days preceding the storm. These high temperatures doubtless melted all of the old snow remaining in the mountains of New Hampshire and Vermont and filled the streams bankful, and it was on streams thus swollen that a 66-hour rain descended on the lowlands and a foot of wet snow on the mountains. By reason of the prevailing temperature the greater portion of the snow water, reached the stream and on account of the duration of the rainfall the run-off from the latter must also have been very great. The flood seems to have been greatest on the lower reaches of the river since the stage at Holyoke, Mass., was exceeded by the flood of October, 1869, 15 years later.

In any event the occurrence of the greatest flood of 300 years in New England seems to have been due to a particular combination of meteorological conditions, viz, the juxtaposition over New England of low pressure and high pressure at a time of year, and in such relative position, as to cause continued and heavy precipitation for 66 hours. No like combination has presented itself since that time, although a somewhat similar combination was present in October, 1869. At that time of year there was no snow to augment the run-off and the streams were not at a high stage.

As illustrating the rule that even great floods are a more or less local phenomenon Table 3 has been prepared. Compare for example the records for Pittsburgh and Cincinnati, both on the Ohio River.

TABLE 3.—*Year of occurrence of great floods at the places named.*

Station.	Order of magnitude of floods, Nos. 1 to 11, inclusive.										
	1	2	3	4	5	6	7	8	9	10	11
Hartford, Conn.	1854	1862	1843	1869	1896	1859	1841	1913	1901	1895	1902
Lawrence, Mass.	1896	1852	1870	1895	1901	1878	1869	1902	1862	1859	1877
St. Louis, Mo.	1844	1903	1892	1909	1908	1883	1881	1904	1917	1882	1876
Cincinnati, Ohio	1884	1913	1883	1907	1918	1898	1897	1901	1890	1882	1899
Pittsburgh, Pa.	1907	1884	1902	1913	1891	1861	1908	1862	1904	1897	{1860 1905
Chattanooga, Tenn.	1867	1875	1886	1917	1884	1890	1918	1902	1896	1882	1899
Nashville, Tenn.	1882	1890	1918	1884	1886	1874	1891	1897	1913	1912	1880
Augusta, Ga.	1908	1888	1912	1891	1913	1918	1887	1902	1903	1889	1892
Little Rock, Ark.	1844	1876	1872	1877	1892	1904	1898	1916	1884	1885	1908
Kansas City, Mo.	1844	1903	1908	1915	1909	1917	1881	1904	1892	1883	1907

EUROPEAN RIVERS.

Naturally one turns first of all to the Danube, a river rich in historical associations, with a history covering a span of more than a thousand years. Unfortunately the flood record for this stream consists of an almost endless recital of floods beginning in the eleventh century and ending with two disastrous rain floods at the end of the nineteenth century. It is quite impossible to class the floods according to magnitude, except as indicated in the next paragraph. In passing, it may be remarked that systematic gagings of the Danube began in 1826.

The following note appears in a chronological statement of floods in the Danube.[5]

> Among the old high-water marks on the Danube stone bridge at Vienna, that of February 26, 1830, takes the highest place, followed by those of February 14, 1776, February 13, 1795, February 24, 1799, March 19, 1740, January 21, 1880, February 4, 1862 (ice free), July 18, 1736 (ice free), and March 5, 1803. Of the marks within recent times, those of September 17, 1899, February 10, 1893, August 2, 1897, January 3, 1883, and June 9, 1892, stand in the seventh, eighth, ninth, tenth, and eleventh positions, respectively, and that of September 5, 1890, in last place.

[4] MONTHLY WEATHER REVIEW, 44: 287.

[5] Report of the Central Bureau of the Austrian Hydrographic Office, Engineer Ernst Lauda, on the "High Water Catastrophe of 1899."

The record here covers 15 floods within a period of 178 years. The total number of great floods in the Danube in the nineteenth century was 10, a greater number than on any other European river examined.

My disappointment in the flood record of this stream is lessened somewhat, however, by the fact that there is no river in North America that parallels it in many of the essential features which produce floods. The source of the Danube is at an altitude of about 2,100 feet, and in north latitude 48° 30′ to 49°. It flows thence east-southeast, receiving the flow of many mountain tributaries, and after pursuing a tortuous course for about 1,730 miles, empties into the Black Sea in latitude about 45°. Were we to superpose the course of the Danube upon a map of the continent of North America, its source would lie in Manitoba and its mouth in the neighborhood of Eastport, Me. By reason of its high latitude and the mountainous character of its upper watershed, the spring break-up of the ice is the prime cause of destructive floods. The occurrence of two very destructive rain floods, viz, those of July–August, 1897, and September, 1899, is described in two memoirs of the Austrian Hydrographic Bureau issued in 1900. The closeness of the net of rainfall and river-gaging stations in Austria makes it possible to present the details of the flood phenomena with a fullness that is greatly appreciated.

The direct cause of the September, 1899, flood, said to have been the greatest *rain* flood of a century, was a six-day period of constant and rather heavy rains over a strip of country about 250 miles long and 100 miles wide. The volume of the precipitation over the watershed of the Danube above the mouth of the March River, area about 40,000 square miles, was nearly 16 cubic kilometers, not so great as in the March, 1913, floods in the Ohio Valley. It is interesting to note that this heavy precipitation was due to the slow movement of a large cyclone that persisted over lower Austria from September 8 to 14, 1899.

THE SEINE AT PARIS.[6]

Systematic gagings of the Seine at Paris extend back to 1649. During the 271 years that have elapsed since that time, there has been one great flood and many lesser floods. Curiously, the record flood of the period was made in 1658—but nine years after the beginning of observations, the nearest approach to that flood in subsequent years was in January, 1910, when the stage fell 1 foot short of that of the 1658 flood. I have tabulated the Seine floods exceeding 20 feet on the La Tournelle Bridge at Paris from 1649 to 1919. These floods number 22, distributed as follows: Seven occurred in the last half of the seventeenth century, seven each in the eighteenth and nineteenth centuries, and a single great flood has occurred thus far in the twentieth century, and at this time the second great flood of the twentieth century at Paris is prevailing.[7] The table follows:

Floods above 6 meters (19.68 feet) in the Seine at Paris, 1649–1918.

	Feet.
February, 1658	28.9
January, 1910	27.9
December, 1740	25.9
January, 1650	25.5
February, 1649	25.2
March, 1711	24.9
April, 1690	24.6
January, 1802	24.2
June, 1697	23.9
March, 1844	22.9
February, 1764	22.6
February, 1799	22.6
March, 1751	21.9
March, 1784	21.9
March, 1807	21.9
February, 1679	21.5
March, 1876	21.3
June, 1693	21.3
December, 1836	21.0
March, 1817	20.6
December, 1801	20.3
February, 1784	20.3

From the record of the Seine floods, the following inference may be drawn. In a long series of observations the number of great floods per century is substantially the same. The intensity, however, varies from one century to another, and there appears to be a tendency to occur in groups rather than singly and at widely separated intervals. The interval in years between great floods does not seem to bear any relation to the intensity of successive floods.

In passing, it should be noted that three extraordinary floods occurred at Paris in the space of nine years—1649 to 1658—whereas in the succeeding centuries the interval was always much greater.

RIVERS OF GERMANY.[8]

In general, river gagings for German rivers are not available, except for a few localities, before the nineteenth century. The record for the nineteenth century, however, seems to be complete.

The Neckar.—The highest water of the nineteenth century on the Neckar was reached in the year 1824, with a gage height at Diedesheim of 1,074 centimeters above zero. Other important floods on that river during the same century, arranged in the order of their magnitude, were:

	Centimeters.
1824	1,074
December, 1882	845
March, 1845	804
February, 1850	780
August, 1851	717
February, 1862	711
January, 1834	705
March, 1896	589

In all, 8 great floods.

The Main at Frankfurt.—The highest water of the nineteenth century was reached at Frankfurt-on-Main in March, 1845, gage height, 728 centimeters; other floods were:

	Centimeters.
December, 1882	728
November, 1882	706
February, 1862	648
February, 1876	632
February, 1850	610
March, 1831	610
January, 1841	583

In all, 8 great floods, as on the Neckar.

The Rhine at Coblenz.—The greatest floods of the nineteenth century in the Rhine at Coblenz were in March–April, 1845, November–December, 1882, and December–January, 1882–83; gage heights, 920, 913, and 834 centi-

[6] Manuel Hydrologique du Basin De La Seine, Paris, 1884.
[7] New York Times, Jan. 3, 1920.

[8] Der Rheinstrom: Baden Central Bureau Fur Meteorol. und Hydrographie, Berlin, 1889.

meters, respectively. Other floods in the same century were:

	Centimeters.
December, 1819	834
March, 1844	811
March, 1876	811
November, 1824	790
February, 1862	787
December-January, 1833-34	774
March, 1855 (ice flood)	685
March, 1896	—

In the early centuries extraordinary floods in the Rhine at Cologne are said to have occurred as follows:

In summer of 1342.
In February, 1374 (ice free).
In winter of 1425.
In 1432 (ice flood, 1,033 centimeters?).
In winter of 1490-91.
In summer of 1491.
In winter of 1497-98 (ice free).
In January, 1552.
In March. 1563.
In March, 1565.
In March, 1571.
In March, 1573.
In March, 1595 (884 centimeters).
In January, 1651 (ice flood, 923 centimeters).
In March, 1651 (927 centimeters).
In March, 1658 (949 centimeters).
In March, 1740 (ice flood, 933 centimeters).
In January, 1758 (790 centimeters).
In February, 1784 (ice flood, 1,263 centimeters).

This list contains a reference to 19 great floods, of which the probable gage heights of 8 are given. Comparing these gage heights with the gage height of the absolute maximum flood at Cologne for the nineteenth century, it is noted that but two floods in 190 years were greater, viz, those of January, 1758, and February, 1784. The last named, with a gage height of 12.6 meters above zero of the gage, seems to have been the greatest flood on the Rhine at Cologne during the period 1342-1900. It was, however, an ice flood, and must therefore be placed in the category of winter floods intensified by ice conditions.

DISCUSSION.

By ROBERT E. HORTON.

(By letter.)

I have found, as I stated at the meeting, a similar constancy between the maximum and the average precipitation per rainfall day, at numerous stations in the United States, regardless of what the mean annual precipitation might be. I have also found the frequency of occurrence of large amounts of rain per rainfall day, of large total amounts in individual storms, and of large amounts in short-time intervals, as for example, 5 to 60 minutes, and in many cases the frequency of occurrence of maximum floods may all be very satisfactorily represented by an expression of the form:

$$\frac{\phi_1}{\phi_a} = A - b\epsilon - ct^n$$

in which ϕ_1 is the magnitude of an event having average interval of occurrence t, and ϕ_a is the average magnitude of the event. The frequency curve for the determination of the constants in the formula is very readily derived by simply arranging the events in their order of magnitude, and computing the average intervals from the observations. For example, the greatest flood observed in a 50-year record is taken as having an average recurrence interval of 50 years, the second greatest 25 years, etc. Now, the peculiar advantage of this method of study seems to be that whereas maximum events do not occur with sufficient frequency so that their average intervals of recurrence can be accurately determined or estimated from a consideration of the maximum alone, this method of plotting and study makes it possible to derive a curve and usually a very good one, based mainly on events of the same kind, of much more frequent occurrence. In other words, the law of frequency is determined mainly from events well below the maximum. A peculiarity of these curves is that they are practically never parabolic. They can not be represented by straight lines on logarithmic cross-section paper, nor by direct plotting on semilogarithmic paper. Consequently they are not ordinary logarithmic curves, as Fuller assumes in deriving his flood formula. They are, however, well represented by an expression of the type above given. It will be noted that this expression approaches a limit of the value of $\phi_1 = a$ as the recurrence interval t approaches infinity; in other words, it leads to the conclusion that most natural events dependent on rainfall can be represented by frequency curves approaching a certain maximum value as an asymptote, and the method of plotting which I have described makes it possible to determine the position of the absolute maximum or limiting value with considerable accuracy, and without placing any great dependence on meager observations of values near the maximum.

The fact that there is a maximum flood stage for any given stream which is never transcended seems apparent. The cause of this physical limitation of hydrologic events dependent on rainfall is also apparent. Actually, it seems to me that the causes contributing to flood magnitudes are so diverse and numerous that their operation may be, for practical purposes, considered fortuitous, in a particular sense, just as the causes which determine which particular face of a dice will come uppermost are so numerous and complicated that the actual result is what we call "a result of chance." But there is a limit in both cases. In throwing a dice, the highest number which can be thrown is 6. A better illustration is obtained by considering the effect of throwing together several dice, say 100. The greatest number which can possibly be thrown is 600. The chance of throwing other numbers less than 600 is not, however, equal, because there are many ways in which some smaller numbers may be thrown, whereas there is only one combination that produces 600.

Similarly, in the case of floods, the combination of causes which can produce an absolute maximum flood is very much more limited than the number of combinations which can produce an ordinary flood; in fact, it seems to me that the occurrence of increasing magnitudes of such events is essentially of the nature of a phenomenon of exhaustion. The larger the magnitude, or the greater its departure from the average magnitude of the event, the greater is the difficulty of its occurrence. The difficulty of occurrence, to use a nontechnical expression, of an event of large magnitude apparently increases in about a geometric progression as the magnitude increases in an arithmetical progression. In other words, the law is similar to ordinary laws of exhaustion applying to various physical phenomena.

This affords a semirational explanation of flood frequency formula, as above given. Now as the duration of a record increases, the maximum event or magnitude increases approaching the limit, and the average value of

the event approaches the true mean as a limit. Since the two values are constant, their ratio is constant for a given stream; in other words, the ratio ϕ_1 to ϕ_a approaches a constant limiting value as the duration of the record increases.

Now, for different streams in the same region, the causes which operate to produce floods operate in the same way, but in different degrees both for different streams, and for different floods of the same stream. Apparently any condition which tends to increase the maximum flood stage increases the average flood state in about the same degree, consequently the limiting values of the ratios of ϕ_1 to ϕ_a may be very nearly the same for different streams in the same region.

THE RELATIONS OF WEATHER AND BUSINESS.[1]

By ARCHER WALL DOUGLAS, Simmons Hardware Co., St. Louis.

[Excerpts.]

Agriculture is, and probably will be for generations, the main business of this country and the main foundation of its continuing welfare. Agriculture is largely dependent upon the weather for its results, especially in those sections and States west of the Mississippi River, where the annual precipitation sometimes varies from 10 inches to 30 inches. Obviously, any intelligent and reasonably accurate long-distance forecast of the probability of weather happenings will be of incalculable value to the business world in such States and sections, seeing that all business in such regions hangs largely upon the results of agricultural production. * * * Such a forecast, in the present state of our knowledge of the weather can not possibly be absolutely accurate, as everyone would certainly, even though unreasonably, expect it to be. * * *

[Some attempt at such a forecast] has been essayed by the committee on statistics of the Chamber of Commerce of the United States, as set forth in their two bulletins, "The Relations of Business and Weather in Relation to Rainfall" and "In Relation to Temperature" [1919]. The general method followed in this investigation, extending over a long number of years, concerned itself as much with personal travel and study in every section of the country as with mere analysis of figures. For instance, the observer learned that two most important features of the effects of drought upon growing plants, especially corn, in the Great Plains States are as to whether such droughts were marked by the presence or absence of exceedingly high temperatures and hot winds. * * *

The basis of the two bulletins of the committee on statistics is [that] the weather has a tendency to recur in the way of the extremes of heat and cold, rainfall, and the lack of it. Also, in common with most other things in nature, that the same kinds of seasons have a tendency to flock together in the way of the association of dry years with dry years and wet years with wet years for a comparatively brief period. There are unexpected exceptions to this tendency, but in an experience of a number of years this general statement has proved to be fairly reliable for business purposes in from 75 to 80 per cent of the time—which of course is rather better than guessing or trusting to that rather absurd law of averages in such a case, or consulting the wishbone of the goose or a local almanac. * * * So it was perfectly immaterial for the purposes of practical business, whether the theory proved mathematically correct when it indicated, some months in advance, the mild open weather of the winter of 1918–1919 and the wet spring and summer of 1919 for the locality of St. Louis and vicinity; also the comparatively colder autumn of 1919 as compared with the similar period of 1918.

[In the southern Great Plains, which for two or three years previous to 1919 suffered from severe drought, and in the northern Great Plains, where a long drought ended in the fall of 1919, it is reasonable to expect relatively favorable conditions in 1920.]

Let us consider the value of a possible forecast of the weather, some months hence, in relation to the sale of what are known as seasonable goods, namely, goods which sell only at certain seasons and then because of the prevalence of certain kinds of weather. Lawn mowers, for example, in wet weather because grass grows best then, and rubber hose naturally sells best in dry weather. These goods have to be made up by the manufacturer and contracted for by the distributor many months in advance of their actual use by the consumer. Whether the weather be wet or dry very seriously affects the sale of both of the lines. Now, suppose a distributing house handling both lawn mowers and rubber hose wished to find out in August, 1918, about how they should order these goods for the coming season of 1919 compared with their sales in the season of 1918 just past. The theory I have spoken of forecast very definitely a wetter spring and summer in 1919 than in 1918 in the vicinity of St. Louis, and that is exactly what happened. Now, suppose this same house wished to know in February, 1919, what kind of an autumn and winter 1919–20 would prove, as to temperature and snowfall, as compared with the similar season of 1918–19, as affecting the sales of ice skates and snow shovels. The theory answers, a somewhat colder autumn and winter and rather more snow. Now, these incidents are the stories of actual happenings. It needs only a little thought to have you realize the far-reaching benefit to business of any system of weather forecasting which will indicate, if only approximately, what kind of weather may be expected in the near future. * * *

DISCUSSION.

Prof. A. E. Douglass called attention to the fact that the recent drought in the southwest was the worst since 1821.

Mr. A. W. Douglas showed that the climate in the southwest has not changed, but that after two or three years of unusual rainfall a dry year may be expected. Business men in that region, however, have gone on preparing for more wet years.

Prof. J. Warren Smith mentioned that a tabulation of 35 winters in Ohio have indicated, as Mr. Douglas had pointed out, that the general character of a winter could be determined by probability.

Prof. H. J. Cox said that the studies of Mr. Douglas are rather more of probabilities than meteorology, and inquired if there is any reason to suppose that a warm winter will follow a warm one.

Dr. C. F. Brooks replied that these changes in the character of the winter are controlled by centers of action, and if, in turn, through such studies as those of ocean temperatures, the general forecasting of the location of such centers of action can be accomplished, the general character of the season can be forecast with more basis than simple probability.

Dr. F. L. West remarked that the prospective purchaser of a water power plant in Utah inquired concerning the relation of the rainfall of the last 10 years to the 35-year mean and found that it had been 25 per cent in excess of normal, whereupon he was somewhat skeptical regarding his purchase, since the succeeding years would probably not yield so much water power.

[1] Presented before American Meteorological Society, St. Louis, Mo., Dec. 30, 1919.

DETERMINATION OF METEOROLOGICAL CORRECTIONS ON THE RANGES OF GUNS.[1]

By WALDEMAR NOLL, Proof Assistant.

[Dated: Aberdeen Proving Ground, Md., Jan. 26, 1920.]

SYNOPSIS.—A projectile in its flight spends more time in the upper part of the trajectory because of its lower vertical velocity, so that when correcting for range and deflection the winds in the upper regions have more time to affect the range or deflection of the projectile and should be given more consideration or weight than the winds lower down. The less dense air composing these upper winds and the decreased horizontal velocity are other factors that must be taken into consideration in order to properly determine the weight that the winds at various heights should be given.

The resistance offered a projectile in its flight varies with the density of the air, other factors being constant. The density aloft is computed from values of pressure and temperature determined from airplane flights. The ratio of observed to normal is then computed and used in making the corrections.

A change in the velocity of sound arising from a change in temperature has the effect of changing the air resistance law of a projectile; hence changing the range of a projectile. Ballistic temperature is computed from values obtained from airplane observations of temperature and by the use of temperature weighting factor curves. These curves are of such a nature that the ballistic temperature may be lower than the lowest actual temperature.

INTRODUCTION.

In the range tables for the various guns the ranges are given for normal meteorological conditions of wind, air density, and air temperature. When these normal conditions do not exist, which is nearly always the case, it becomes necessary to correct range and deflection to the existing meteorological conditions.

Previous to 1917, the principal corrections for meteorological conditions were made, using surface conditions. But surface meteorological conditions seldom represent the upper air conditions prevailing through the whole trajectory, as the winds aloft usually have different velocities and directions from those on the surface, while the decrease of density and temperature as the altitude increases is very irregular. Consequently, the existing meteorological conditions aloft must be taken into account in making the corrections. Because of the many factors that affect a trajectory, the meteorological conditions at different altitudes must be specially considered or weighted in order to properly make the corrections for range and deflection. To properly consider these factors, terms have been introduced known as ballistic meteorological conditions, namely, ballistic wind, ballistic density, and ballistic temperature. A ballistic meteorological condition is an imaginary one, which has the same effect on a trajectory as the true conditions that do exist within the limits of the trajectory.

It has been with the aid of ballistic meteorological conditions of this sort that the new range tables have been constructed. Therefore, it is also necessary, when these tables are used, to take range and deflection corrections for the existing meteorological conditions, using similar methods.

In order to clearly understand the corrections for wind it is necessary to consider briefly a few facts about the flight of a projectile. A projectile in its flight spends more time in the upper part of the trajectory because of its lower vertical velocity, so that when correcting for range and deflection the winds in the upper regions have more time to affect the range or deflection of the projectile, and should be given more consideration or weight, than the winds lower down. The less dense air composing these upper winds and the decreased horizontal velocity are other factors that must be taken into account in order to properly determine the consideration or weight that the winds at various heights should be given. The weight that should be given the winds at different altitudes are found in wind weighting factor tables that are incorporated in the range tables for the various guns. Using the factors from these tables and the wind velocities obtained from the Meteorological Section, a fictitious or resultant wind is computed which is used in making the range and deflection corrections for wind. The wind is known as ballistic wind and has the same effect in changing the range or deflection as the winds that actually exist. Ballistic range and cross winds must be computed using the respective range and cross wind weighting factors.

The weighting factors are obtained from weighting factor curves which have been computed for the various guns by a series of differential corrections.

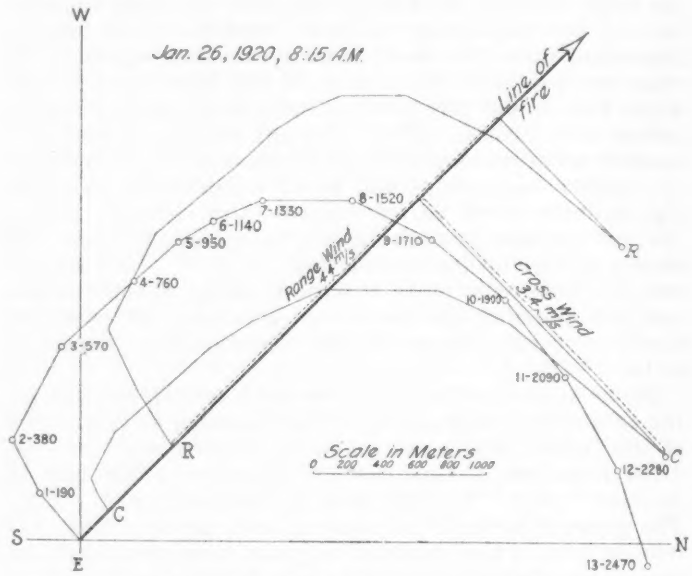

FIG. 1.—Determination of range and cross winds.

The velocities and azimuths of the winds aloft for equal zones of altitude, such as 250 meters, are determined by observing the flights of pilot balloons by theodolites. For the particular gun to be fired and for the definite range to be obtained each 250-meter zone up to the maximum ordinate of the projectile has a certain weighting factor for both range and cross wind. The weighting factors for the various zones are then multiplied by the wind velocities for the corresponding zones, and two columns of values established. On the plotting board the line of fire is laid out. (See fig. 1.) Beginning at any convenient points on the line of fire two lines are drawn parallel to the azimuth of the wind for the first zone. On these lines are measured out, respectively, the products of range and cross wind weighting factors and velocities. From the two points determined two additional lines are drawn parallel to wind azimuth of zone two and on them are laid out the products for the second zone. This is continued until the values for all the zones have been plotted. From the final points determined, perpendiculars are dropped to the line of fire, thereby completing the polygons. In the range-wind polygon the distance from the first point on the line to the foot of the perpendicular, after being reduced to

[1] This paper is not in anywise to be taken as an official statement from the Army.

scale, equals the ballistic range wind and is given in meters per second. If this wind tends to increase the range it is positive, and if it tends to decrease it is negative. In the cross-wind polygon the length of the perpendicular itself gives the ballistic cross wind. If the wind tends to deflect the projectile to the right it is positive; to the left, negative. The values of ballistic winds are then used in correcting the ranges.

BALLISTIC DENSITY.

The resistance offered a projectile in its flight varies with the density of the air, other factors being constant. A decrease in density corresponds to an increase in range and vice versa. Consequently it is necessary to know the density of the air to the height to which the projectile rises, in order to properly determine the ranges. After the values of pressure aloft, vapor pressure aloft, and temperature aloft are obtained by use of airplanes or kites, the densities are computed and plotted against true height. From the density curve thus drawn the densities for every 250 meters altitude are read off.

We are now ready for a consideration of ballistic density, "ballistic density may be defined as an average or resultant ratio of observed density to normal density, determined by properly weighting the ratios of observed density to normal density, throughout the zone under consideration—that is, from the surface to the height of the maximum ordinate of the trajectory for which the ballistic density is being obtained. Normal surface density is taken as 0.001206 grams per cubic centimeter. The ratio of normal density at an elevation of y meters, to normal surface density is equal to $\epsilon - .0001036\ y$.

When the time of the aeroplane or kite flight is the same as that of the firing of the gun, the density chart may be used as it stands. Densities at intervals of 250 meters from the surface to the height of the maximum ordinates are read off, and normal densities for the corresponding heights are subtracted from them. The differences thus obtained may be averaged directly. But the question of properly weighing these ratios comes in at this point. Fortunately nearly all weighting may be neglected, as the weighting factors are, in general, nearly the same for all zones except the top. The correct weighting if approximately obtained by giving the bottom and top zones double the weight received by the rest. This is directly accomplished by simply averaging the differences as they stand, inasmuch as they are the differences at each height and not of each zone, as already explained.

This average thus obtained is the ballistic density, and is used in obtaining a proper correction for an observed range.

When the time of the firing does not coincide with the time of the observation, a slight change in the density chart may be necessary. From the surface temperature and pressure at the time of the firing the surface density is figured and plotted as a point on the chart. From this point a line is drawn which is made to converge gradually with the density curve. The density curve with this correction is more or less a matter of judgment. From a study of density aloft, it is apparent that the density changes from hour to hour are usually greatest at the surface, decreasing with altitude, and become very small at the height of 1,500 meters in winter and 2,000 meters in summer.—[Extracted from memorandum by O. P. Camp.]

BALLISTIC TEMPERATURE.

It is well known that the change in the velocity of sound arising from a change in temperature has the effect of changing the air resistance law [of a projectile], principally in the neighborhood of the velocity of sound, and hence of changing the range of a projectile whose velocity at some part of its path passes through or strikes into the velocity of sound regions. [Extract of memorandum by Dr. Graustein.]

Ballistic temperature used in making the corrections for range may be defined as a resultant or fictitious temperature obtained by properly weighting the true temperatures for every 250 meters from the surface of the earth to the height of the maximum ordinate.

Accordingly, two range tables for the same gun and projectile, made up on the basis of firings during opposite seasons of the year and not corrected for temperature, might well differ by as much as 3 per cent. In fact, discrepancies between -millimeter shrapnel tables have been traced precisely to this cause. [Extract of memorandum by Dr. Graustein.]

In computation of ballistic winds, results approximately correct may be obtained without weighting the true winds in the various zones; ballistic density can be obtained without weighting the true densities; but ballistic temperatures must always be determined by weighting the true temperatures. A study of Temperature Weighting Factor curves shows that the factors for the lower zones are negative. Because of these negative values it is entirely possible to have a ballistic temperature lower than the lowest true temperature. It is thus seen that some average or mean temperature would not be correct.

APPLICATION OF METEOROLOGY TO GUNNERY.[1]

By ERNEST M. WEDDERBURN.

Space will not permit a complete review of the material covered in this paper of 22 quarto pages, which has been issued by the Experimental Establishment, Shoeburyness, 1919; but those interested in the subject will find it an interesting and valuable reference. It consists essentially of three parts, the first treating of meteorological variations in still air, the second, of air in motion, and the third, of practical applications. There is a preface by Lieut. Col. Ernest Gold, in which the progress of the relations between the artillerist and the meteorologist is traced through the war. The concluding words of the preface give very adequately the value of the research of which the paper is a report:

"As may be expected, the information so obtained has other uses: It furnishes aviators with the means of accurate navigation; it throws light on many of the apparent idiosyncrasies of meteorological charts; and it gives the weather forecaster practical certainty in many situations which would otherwise be almost guesswork.

"The need of an authoritative summary of the results achieved, both in practice and in theory, and of the practical problems still awaiting solution, has been apparent for some time, and meteorologists and gunners will both benefit by Capt. Wedderburn's exposition."—*C. L. M.*

[1] A briefer discussion is published in the Journal of the Scottish Meteorological Society, 1919, vol. 18, 3d ser., no. 36, pp. 86-92.

THE SIGNAL CORPS METEOROLOGICAL SERVICE, A. E. F.[1]

[Excerpts from Annual Report of the Chief Signal Officer, 1919, pp. 352-356, 5 photos, 1 diagr. In other parts of this report are to be found: Details of personnel and organization, pp. 38-40; details of the meteorological schools, pp. 86-87.]

The meteorological work [for the U. S. Army] was planned as a result of investigations [of existing services, of terrain, and of French weather] and orders were placed for equipment in order that when personnel began to arrive in March, 1918, its instruction both in observational and forecasting work might be taken up without delay. The observational work included, first, data on wind effects for use of artillery; second, the determination of upper winds for use in aviation work; third, such observations as were required for forecasting, in addition to data supplied by the French Bureau Meteorologique Militaire and the British Meteorological Service, both of which received in return such meteorological data as they desired from the Meteorological Section, Signal Corps, American Expeditionary Forces. Later, certain observations desired for sound-ranging units were added. * * *.

The first American meteorological stations were established early in May, 1918, the first observation being made on May 9 at Ourches (Meurths et Moselle) in the zone of advance at the flying field of the First Corps observation group. Other stations were established at aviation and artillery training centers in the area of the Services of Supply, where they took part in the regular training programs, both by obtaining experience for their own personnel and by furnishing data for the use of other services.

The meteorological stations functioning in the battle areas were in general equipped with wireless, which was used to communicate the meteorological information to the desired points. The stations were situated near the headquarters of the army corps and were in connection, by telephone when possible, with the corps headquarters. The first station to take part in combatant operations was the one which operated with the First Army Corps when this corps entered the lines near Chateau-Thierry. This station furnished artillery and aviation with the necessary meteorological information. During the advance the station moved forward with the corps, being located at the position of one of the observation balloons and remaining in the area until the army was withdrawn.

Another station furnishing artillery data to combatant troops was established on July 27, 1918, near Royaumeix (Meurthe et Moselle) in the area occupied by the Fourth Army Corps. This station operated continuously furnishing artillery data for all trajectories every four hours, day and night, from the time of its establishment until three days after the signing of the armistice, when orders were received, from the office of the Assistant Chief Signal Officer, to discontinue the work. The station remained at its locality until it moved forward with the corps during the St. Mihiel drive, so that observations were made at practically all times within 6 to 10 kilometers of the front-line trenches. At times this station was under shell fire, at one time the shells dropping within 30 meters; at least one observation was made during a gas alert. The information of wind speeds was greatly desired by observation balloon officers, who appreciated its usefulness more particularly after one case when the balloon officer doubted the data and sent his balloon up until the winch began to rise from the ground.

At 11 p. m., October 18, [1918,] a request was received at headquarters, Army Meteorological Stations, for the immediate establishment of a station near Verdun, in connection with the heavy long-range railway artillery which was installed in that vicinity. This necessitated, in addition to the selection of the personnel and its transportation with equipment for a distance of more than 100 kilometers over congested roads, the determination of reduction factors for 10,000 meters, 5,000 higher than the existing tables permitted. The station was operating and data being furnished the artillery within 26 hours from the time the request was received. * * *

The stations operating in the army areas, in addition to the sending out of observations by radio every four hours, made special observations whenever called upon by artillery, aviation, gas, and sound-ranging units. There were also continual calls for special information and other types of cooperation with operating units which were handled informally by the men of the detachments; so varied and numerous that the record would be long. In most cases forecasts and special wind-warning were communicated to these detachments and distributed by them to the operating units concerned. * * *

Forecasting began at the headquarters station of the Army Meteorological Stations, at Colombey les Belles (Meurthe et Moselle). On August 16, 1918, the first forecast of the Lorraine sector was issued to the American First Army. This forecast included a statement of the weather conditions relating to operations for each arm of the service, followed by detailed forecasts of the wind direction and speed, both at the earth's surface and in the upper air, conditions of the sky, cloud height, visibility, precipitation, fog, haze, temperature, and, when needed, statements that weather conditions were favorable for the use of gas by the enemy.

A unique feature of this forecast was the statement at the end as to the probable accuracy of the forecast. The accuracy was expressed in odds in favor of the forecast. For example, odds of "five to one" indicated that in the opinion of the forecaster there were five chances to one in favor of the forecast being correct. By this statement of odds it was possible to make the forecast absolutely definite and such qualifications as "probable" or "possibly" have never been used. The material upon which the forecast was based was that received from our stations, 25 in number, from the French Meteorological Service, and from the British Meteorological Service. To facilitate the receipt of French and British reports a Signal Corps telegraph office was opened at Dugny, Seine, the headquarters station of the Service Meteorologique aux Armees. These reports included the usual elements of the International Weather Code.

Informal cooperation of the most satisfactory character was maintained with the Meteorological Section of the Royal Engineers attached to the Independent Force of the British Royal Air Force, and later, when Capt. Brunt moved to Autigny-la-Tour (Vosges), complete information from the British Isles was telephoned four times daily to Colombey les Belles. Forecasts were made on the basis of four weather maps a day drawn from the foregoing information.

At first a forecast was issued at 6 p. m. covering a 24-hour period and another at 8 a. m. covering a 12-hour

[1] For discussions of the meteorological work of the Signal Corps in the United States see MONTHLY WEATHER REVIEW, 1918, 46: 555-562; 1919, 47: 84, 210-225.

period. This forecast was sent by telegraph to army and corps signal officers and to the Air Service. These units repeated the forecasts to the operating units directly concerned. The Air Service soon found it desirable to have a forecast made in the early afternoon covering the late afternoon and the first part of the night, particularly for use in connection with bombing and artillery observation.

Owing to the congested condition of telegraph wires as the First Army advanced in the Argonne area, the forecasters became convinced that an early issue of the forecast was desirable. Upon studying the situation it appeared that telegrams from the Signal Corps meteorological stations of the Services of Supply at 1 a. m., together with the 1 a. m. observation sent by telephone by the British, would permit of the construction of a satisfactory weather map, and the morning forecast was, therefore, issued between 5 and 6. The early arrival of the British data also permitted the afternoon forecast to be made before 6 p. m., and these changes were accordingly made. * * *

From information received from Artillery, Aviation, and General Staff officers, it appears that practically all bombing and a great deal of the artillery, gas, and other operations of the First and Second Armies were based upon the weather forecasts issued by the Meteorological Section of the Signal Corps. Gen. Mitchell stated that the forecasts were indispensable to the operations of the Air Service. The stations maintained by the Meteorological Section furnished timely notice of all squalls, and squall warnings reached all Air Service units before any squall reached the lines. Timely notice of all dangerously high winds at the 300 and 800 meter levels was also given. * * *

When the American Expeditionary Forces entered the field the Service Meteorologique aux Armees had developed a method of determining wind direction and speed above a cloud sheet; the method of "Sondage par le son." A study of this method showed that it was entirely feasible, and the results obtained by the French stations were used in determining artillery winds, and in weather forecasts on cloudy days. When the armistice was signed arrangements had been practically completed for taking over and operating as a part of the Meteorological Section, Signal Corps, American Expeditionary Forces, the Sondage par le Son station at Chaumont sur Aire (Meuse).

Two factors essential to the success of the Signal Corps Meteorological Service should be mentioned. The first of these is the faithful and capable personnel which was furnished for the work. It was largely through the efforts of the Science and Research Division of the Signal Corps in Washington that the supply of these men was continued up to the end. The second factor is excellent communication service furnished. In spite of the fact that the meteorological messages are difficult of transmission and require night as well as day service, communication once established was thoroughly reliable. Failure in either of these essential elements would have rendered the work of the section less efficient in both the local and the forecast services.

NOTES ON THE METEOROLOGICAL SERVICE IN THE GERMAN ARMY FROM TRANSLATIONS OF GERMAN DOCUMENTS.[1]

(From Bulletin de la Meteorologique aux Armees, January, 1918, pp. 65-79.)

Translated by C. LeRoy Meisinger.

I.

THE RÔLE OF THE METEOROLOGICAL SERVICE.

The documents analyzed show that the meteorological service in the German Army experienced a great development and that the command attached a high importance to all the reports furnished by the stations and the secondary posts. These reports were then adapted to the needs of modern warfare.

Forecasting.—The meteorological bulletins and the forecasts for the succeeding 12 hours were communicated twice daily, in the morning and in the evening. The bulletin contained:

1. A general forecast.
2. A forecast for wind. (Probable direction of the wind for the next period of 12 hours.)
3. A discussion of the possibilities for the use of gas shells. (**C**.)[2]

Collaboration with artillery.—For the useful employment of artillery tables, collaboration with the meteorological service was necessary. The new organization of the meteorological service of the army and of the artillery satisfied this necessity. The meteorological information ought to be communicated at least three times daily, or more frequently if the need for it arises, especially at night, and in case of a sudden change. The reports contain:

1. Direction and speed of the wind in meters per second (if possible to an altitude of 2,000 meters).
2. Barometric pressure at the altitude of the battery.
3. Temperature. (**E**.)

Conforming to these instructions, the artillery command says, in its note of September 5, 1917: "The meteorological bulletin is issued three times daily. Each bulletin remains in force until the arrival of the next (except for precise firing, when the mean trajectory of the projectile is greater than 500 meters, and also for firing at night; in this case, it is necessary to have readings of barometric pressure and temperature immediately before firing). If, in the meantime, changes in the direction of the wind are noted, corrections are made by approximation." (**F**.)

For the execution of these requirements, a special service was created in the division. "A section, charged with the recording of atmospheric conditions (*Tageseinflusstrupp*), is created for the division. Between 6 a. m. and 6 p. m., every four hours, the *Tageseinflusstrupp* takes the barometric pressure and the temperature of the air, and from these given values the density of the air. The surface wind speed is noted at the same hours. Soundings are made in the morning, at noon, and at 6 p. m. The results are telephoned to the various units.

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[1] (**A**) *Le service de surveillance contre les gaz dans l'armee.*—No. 7837, E. M. de la III armée, du 28 octobre 1916.
(**B**) *Tir de projectiles de Minenwerfer a gaz.* (Indications meteorologiques.)—Groupe d'armees du Prince heritier de Baviere.—E. M. Genie.—No. 8315, du 31 janvier 1917.
(**C**) *Organisation du service meteorologique du front.*—No. 432/17 du Q. G. de la 52e D. I., du 9 aout 1917.
(**D**) *Instruction provisoire pour le service meteorologique du front de la VIIe armée*, du 13 juillet 1917.
(**E**) *Perfectionnement de la precision des tirs d'artillerie.*—G. Q. G. allemand.—Mo. 60.336 op., Ludendorff, 20 juillet 1917.
(**F**) *Etude sur l'utilisation rationnelle des tableux journaliers de corrections atmospheriques.*—Commandement de l'artillerie.—No. 6783/17/1, du 5 septembre 1917.
(**G**) *La guerre mondiale.* (No. du 1er decembre 1917.)—*Le service meteorologique dans l'armee allemand.*
H) *Collection de bulletins meteorologiques.*

[2] Capital letters refer to documents listed in footnote 1 from which this information has been obtained.

In case of special operations, or upon request of the batteries, special observations are made also at night." (**F.**)

Service for surveillance against gas.—In the Third Army the reports on the current wind at the front are transmitted to the field meteorological station by:

1. The posts of aerial surveillance (*Fliegerwarten*) distributed behind the lines and supplied with wind vanes.

2. Posts for observing the wind (*Windwarten*),—a part of the army corps—situated a few kilometers in the rear of the lines, in places chosen by the chief of the meteorological station. They are occupied by two men. The chief of the meteorological station instructs the men on their work, and they are furnished the necessary instruments and other materials necessary to fulfill their mission.

These posts ordinarily take their observation at the regular hours, 6 a. m., 12 noon, and 8 p. m. and telephone the report to the chief of the meteorological station.

In the meantime, they watch the direction of the wind, with attention to possible changes. Especially do they watch for wind conditions favorable to the enemy, in which case the information is communicated without delay to the meteorological station. When the meteorological station, basing its conclusions on proper observations and upon the reports rendered by the observation post, deems that a gas attack is possible by the enemy, it warns the interested divisions.

If there is a change in the atmosphere indicating a diminution of danger of attack or complete cancellation of it, the divisions are so informed by the meteorological station.

The meteorological station is held responsible at all times for reports on the wind and general atmospheric conditions. (**A.**)

Conditions favorable for the use of gas shells.—For the rational use of gas shells, particularly in harassing fire, the creation of a meteorological service seemed necessary, as much for the companies of *Minenwerfer* as for the *Minenwerfer* formation in the infantry. This service was usefully attached for the meteorological observations for protection against gas.

In this manner, at the Sixth Army, the field meteorological station was formed for the companies of *Minenwerfer* at the front and for units of *Minenwerfer* in the infantry. This arrangement has given very satisfactory results. (**B.**)

II.

ORGANIZATION OF THE METEOROLOGICAL SERVICE.

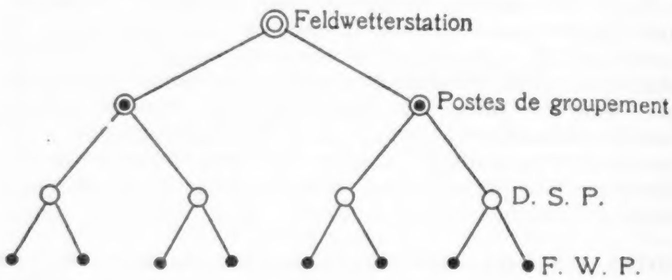
There exists in each army a field meteorological station (*Feldwetterstation*) which gives technical directions to the secondary posts at the front, and which provides instruction to the personnel of these posts. It seems, on account of the progress already realized, the new needs, and the organization already effected, the service ought to be the object of uniform organization, for in his note of July 20, 1917, Ludendorff declared himself for a new organization of the meteorological service of the army. (**E.**)

Also, on July 13, 1917, the commander of the Seventh Army wrote: "The beginning of general meteorological instruction at the front, of value to every army in the field, can not again be accompanied by a set of recent restrictions, for the army can not foresee the recurrence of the last application." (**D.**)

Perhaps one can place the date of the new organization between the 13th and the 20th of July, 1917. In every case it came in response to a pressing need, since the Seventh Army, since the 13th of July, 1917, estimates that the necessary meteorological advice for the operations with the use of gas, as well as for the safety of the troops, necessitated a fixed organization for meteorological service at the front, and, in the absence of a general instruction, prescribes that the following instructions be applied to the whole front of the Seventh Army:

The meteorological service at the front is organized by divisions under the orders of the staff officer in charge of gas or the division gas officer for all which concerns the protection of our troops.

Each division establishes a central division post (*Divisions-Sammel-posten:* D. S. P.) composed of two noncommissioned officers; it will establish beyond some line posts of observation (*Feld-Wetter-posten:* F. W. P.). The D. S. P. and F. W. P. follow the division in its movements.



Schematic diagram of meteorological organization of the Seventh German Army.

Every two hours (at 0 hr., 2, 4, etc.) the F. W. P. reports the direction and speed of the wind and transmits these observations at 6 a. m. and at 4 p. m. by telephone to D. S. P. In special cases, more frequent reports will be issued to the D. S. P. upon the request of the staff officer in charge of gas or the division gas officer.

The F. W. P. will concentrate their attention on all manifestations which might enable the enemy to make a gas attack. They will immediately inform the commander of the sector and will forward a message to the D. S. P. which will be sent to the division gas officer.

The D. S. P. combines the observations of the F. W. P., verifies them, and forwards them weekly to Meteorological Station No. 1 (*Feldwetterstation* of the Seventh Army). With the aid of the reports rendered by the F. W. P. the D. S. P. can constantly keep their division gas officer informed as to the state of the wind for their sector. The D. S. P. will receive regularly the forecasts of the meteorological stations of the front and will take care to forward quickly these reports to respective authorities of their D. I. [?] They are not authorized to give by themselves an opinion concerning the weather. For that, they are required to ask the meteorological station No. 10 which will give them the desired report.

The instruction of the D. S. P. will be given by the meteorological station. They will instruct in turn the F. W. P. The personnel will be chosen from men showing the required aptitude: scientific and technical men.

To complete the forecasting and giving of information on occasion of operations where gas is used, also

to complete the work of the meteorological station on the army front, each group will be posts for meteorological grouping. These posts will be organs of their sector under the technical direction of the staff officer in charge of gas. They will follow the instructions of the meteorological station on all technical questions concerning meteorology. They wll issue regularly to the D. S. P. all forecasts of the *Feldwetterstation*, and will serve as intermediaries in transmitting information regarding storms and squalls. (**D.**)

III.

TECHNICAL REPORTS.

Reproduction of a meteorological bulletin:

BULLETIN OF THE METEOROLOGICAL OBSERVATORY OF CREPY.

Date: *6/9/17.*
Pressure (sea level): *759 mm.*
Humidity: *94%*

Time: *7 a. m.*
Temperature: *13° C.*
Visibility: *Ordinary.*

FORECAST	Altitude (meters).	Wind direction.	Wind speed (m/s).	Altitude (meters).	Wind direction.	Wind speed (m/s).
8 a. m. to 8 p. m.						
1st. Partly cloudy; sky occasionally clear; generally dry.	100	Calm.		1,000	Calm.	
	200	e.	4	1,500	sse.	8
	400	ne.	2	2,000	sse.	11
2nd. Gentle SE. winds.	600	s.	2	3,000	se.	12
3rd. Atmospheric conditions not favorable for us to use gas shells.	800	Calm.				

b. *Transmission by telephone of observations of posts at the front.*—The posts at the front give the direction of the wind in 16 compass points and its speed in meters per second. The tabulation and the telephoned messages are constructed with the aid of the formula WWS, by replacing WW with two figures indicating the wind direction, and S with the number of meters per second which have been observed.

In case of a threatening squall, the word *squall* is added next to the mean speed of the wind, and, if possible, the estimated change of wind direction. If the speed of the wind exceeds the indicating possibilities of the anemometer, the S is replaced by X.

Hour.	Abbreviations.
4 a. m.	*4 v.*
12 noon	*12 m.*
6 p. m	*6 n.*
12 mdn	*12 n.*

Example:

Observation as made.	Message as sent.
North wind, 3 meters per second	323
SSE. wind, 8 meters per second	14 X
NW. wind, 3 meters per second	283
Calm	000 (**D.**)

c. *Material.*—The stations are provided with all the instruments and accessories used in meteorology. As examples one can note that they possessed an automatic rain gage, a cinemograph, and a sunshine recorder. The pilot balloons are of red paper and are provided with a rubber appendix. The observation stations are mounted on towers and have glass windows, oriented in all directions, permitting in case of bad weather, the continuation of observations. (**G.**)

d. *Meteorological indications for the use of gas shells.*—The chief of the field meteorological station of the Sixth Army gives a very precise and detailed report on the meteorological conditions, topographical influence, the observation of wind in the trenches, and on the forecasting of wind for the use of gas shells.

ARMY GROUP
of the
CROWN PRINCE OF BAVARIA.
GENERAL STAFF.
Annex to No. 8315

Field Meteorological Station 6 A. O. K. G.

METEOROLOGICAL CONDITIONS FOR USE OF SHELLS "D."

I. CONDITIONS OF WEATHER.

While, originating from cylinders, the quantities of gas are nearly unlimited for a short time and are carried by the wind against the enemy, gas shells and gas mines carry against the enemy limited quantities of liquefied gas which evaporates slowly. Therefore, the maximum effect of gas shells will be felt in a complete calm, more in a vertical sense than in a horizontal, or when there is only a gentle wind blowing toward the enemy. The upper limit of the speed of the wind in this case is in the neighborhood of 1.5 meters per second.

The calmness of the air increases generally during the night; therefore the early hours of the morning are most favorable for the use of gas shells. The early hours of the night present, among others, a difficulty which invites, in every case the greatest care; especially after sunset, the temperatures at the surface, due to unequal absorption and radiation over varying terrain, tend to equalize themselves. The lower layers of the atmosphere are at that moment agitated by continual and irregular convection, which renders quite possible a turbulent state of air.

In rainy weather, one can not fire, because the rain beats down the gas against the ground. In foggy weather gas shells can be used in certain cases but the density of the air must be taken into account.

The notes on the influence of temperature are to be found in "Instructions on munitions 'D.'"

It is interesting to know in what measure the conditions of wind are favorable for the use of gas.

Contrary to the conditions for firing gas shells, the gas, in the case of firing mines, is more dangerous for our own trenches; for the use of gas mines, the nights are chosen when the air is not completely calm, in order to avoid a very gentle wind blowing the gas back. It is necessary to have a gentle wind blowing against the enemy; also the possibilities of firing are more limited than with gas shells.

On the whole, in central Europe, westerly winds are the most frequent. If we arrange the winds in order of frequence, beginning with the most rare, we obtain the following series: SE., S., E., NE., N., NW., W., SW. The coefficients of relative frequence change a little at each place due to its relation to the ocean; but the series remains nearly the same.

It follows that, in a trench which faces the NW., the gas mines can be fired more rarely than in a trench facing the NE. The other directions naturally vary between.

For firing the gas, it is not always necessary that the wind always blow absolutely against the enemy perpendicular to our trenches; a variation as great as 60° from the normal is permissible.

Theoretically one can admit a scope of 180°, inasmuch as, in this limiting case, the gas carried into the trenches of the enemy will follow the length of the enemy trenches; but, since the wind varies somewhat every day, it is recommended to preserve an angle of safety of 30°.

II. INFLUENCE OF THE TERRAIN.

One can admit in principle that all the terrain which accentuates the calm increases the effect of the gas. Therefore, high stiff grass, brush, etc., retards the movement of the air, although it is possible to fire on this terrain with gas shells as well as when the wind is about 2 meters per second on uncovered land.

The gas being heavier than the air, a terrain which slopes toward the enemy is better to fire upon than a flat surface, a flat surface is better than a rising one, where one is not assured against a reflux except with a wind of more than 1 meter per second.

III. THE OBSERVATION OF THE WIND.

a. *In the trenches.*—To determine the direction of the wind, the ordinary wind vane may be used, but if this is not available it is sufficient to attach a strip of cloth to the top of a stick. The direction which smoke passes above the trenches is also a good indicator. One obtains the best results in lifting the vane above the trench, for in the trench and in the immediate vicinity the local air currents can have a direction different from that of the general movement of the air. The trenches afford a system of depressions which have their own peculiar circulation of air; thus, it is between 0.5 meter and 1 meter above the parapet that the normal wind is found.

Analogous remarks may apply to the determination of the speed of the wind; the best results are obtained with the aid of a Fuess anemometer, universally in use in the field meteorological stations.

It seems that the companies of *Minenwerfer* measure the speed of the wind regularly each evening and each morning, whether or not they intend to use gas. In part the companies are able to know the wind in their sector. At any rate, if the enemy knows that the measure of the speed of the wind is a regular practice, his attention will not be aroused, except that that practice can also be well used by us for protection against gas.

Two other services are interested in the observation of the speed of the wind: First, the company of *Minenwerfer* engaged in the protection against gas, which also has need of good observers at the front. In place of using untrained foot soldiers, the divisions will have the advantage of turning to account the organization of the pioneers.

It follows that during a gas attack the observation of wind speed should be continually made. The observation of the wind direction should be continuous; for the speed of the wind, ordinarily it is sufficient every half hour.

b. *Behind the lines.*—It is recommended to start a smoky fire at a place well chosen in the rear, for example, at the headquarters of the army corps. A line can be traced parallel to the first-line trenches, and the smoke observed with respect to this line. It is possible to deduce from this observation not only the direction and speed of the wind but also its nature. If the smoke trails tranquilly at the surface of the earth, it is advantageous to fire; if, on the contrary, the wind stirs up the smoke, a gas attack will not give the required result.

It is advised to check the direction of the wind obtained from that observation. The best means of doing this is to observe the direction from which sounds seem nearer. This will show the continuous nature of the wind. If the direction indicated by the direction of sound is identical with that observed, one can conclude that the curnr e is homogeneous.

IV. FORECASTING THE WIND.

The forecasting of wind, in the case where a meteorologist can not be found among the pioneers, is demanded of the field meteorological station of the A. O. K. In this connection the following method is recommended:

The meteorological station gives each day, between 6 and 8 p. m., a forecast of the weather good for the following night to E. M. of C. A., and to independent divisions. The E. M. transmit to the front these communications in the interest of protection against gas.

Later, one adds to the text a supplementary mention of the possibility of firing gas mines, indicated "D." The front of the Sixth Army can be divided into elements of like orientation: a, b, c, etc., in which each one is designated a wind with relation to its orientation for use of gas shells. If the meteorological station anticipates an east wind, the supplement will therefore conclude:

"Direction of the wind good for Da, good with reservations for Dd and De."

The wind is said to be "good with reservations" for the sectors d and e because one could not use gas mines in this sector with oscillations of wind exceeding 15°.

This text, conforming to decision II, No. 34.283, op. of September 13, 1916, of the chief of the general staff of the field armies, is intended for combat units. It should be communicated, with necessary orders, to companies of *Minenwerfer*.

When a direct explanation is necessary between the trenches and the field meteorological station it is better not to use the conventional terms to designate the direction of the wind, etc., but to speak of wind in clear language, concerning questions of protection against gas.

Example: A position, situated facing the west, receives from the station the following report:

> You do not need to fear a gas attack to-day, for we can count on a gentle east wind; on the contrary, it will be possible that during the morning the enemy may make a gas attack, for a complete calm is forecast for that time. This applies especially to the places where the slope rises toward the enemy.

It is preferable, when a gas attack is contemplated, that a meteorological consultation will be made by the intermediary of the commander of the pioneer units.

(Signed) V SCHMAUSS.

7th Army, General Staff.
No. 14.883.

General Headquarters 6/2/17.

To be communicated to all the groups, all troops in the rear, and the training schools.

For the Commanding Officer:

V BORRIES,
Major General, Chief of Staff.

SQUALL WARNINGS.

[Abstract of "L'Avertissement des Grains," Bulletin de la Météorologie aux Armées, Oct. 15, 1918, pp. 1-12.]

Squalls, which have proved so dangerous to aviation and destructive in general, through the suddenness of their appearance and the violence of their passage, are characterized by a considerable sudden variation in wind direction, sometimes the appearance of hail, or thunder and lightning, sudden increase of barometric pressure and humidity, and a rapid drop in temperature. There are abundant instances in which aviators, surprised by

the suddenness of the squall, have been lost. Three zones in the life of a squall can be discerned; first, that in which the squall begins, and where it is impossible to give warning; second, that in which the squall reaches its maximum effectiveness, for which warnings are indispensable; and third, that in which the squall is decreasing, in which warnings are unnecessary. The military squall-warning service of the French Army was established to combat the second stage, in which the phenomenon is most dangerous. To determine the existence of squalls and their characteristics, to estimate their force and the danger they present, and to disseminate the information to those interested, were the functions of three distinct divisions in the warning service: The first by the observation posts (*postes d'observation*), the second by the central office where the reports were received, and the third by the *service de diffusion*. The warning service was very efficient and was usually able to warn air-service units three-fourths of an hour before the arrival of the squall; it is estimated that such warnings were given in 85 per cent of the squalls.—*C. L. M.*

FORECASTING LINE SQUALLS IN WEST AFRICA.

By H. HUBERT.

[Abstract reprinted from *Science Abstracts*, July, 1919, pp. 312-313. Original article in Comptes Rendus, 168, Mar. 17, 1919, pp. 567-570.]

From observations made in Senegal in winter it can be shown that line squalls, similar to those experienced in northwest Europe, occur in that region also. The mean direction of propagation is, however, from east to west, instead of from west to east, which is the mean direction of propagation of the line squalls of our latitudes. The mean velocity of propagation is 60 kilometers per hour, the extremes being 44 and 72 kilometers per hour. The direction of the line along which the disturbance is found at any time is generally north-south. The length of the line may exceed 100 kilometers, and the passage of a squall has been traced for hundreds of kilometers Nothing is said as to changes of wind and weather accompanying these line squalls. Further observations are needed in districts adjacent to Senegal in order to investigate these squalls more precisely, but already sufficient stations exist in Senegal to permit of a warning of the approach of the squall to be issued a few hours (up to six or eight) in advance of the event.—*R. C.*

NOTES, ABSTRACTS, AND REVIEWS.

PROGRESS OF METEOROLOGY.

By W. H. DINES.

[Extracts from *Nature*, Nov. 6, 1919, pp. 247-248.]

"The progress of meteorology during the last 50 years has been very marked, as may be seen by a casual reference to the current meterological literature of the period 1865-1875; to a great extent, it resembles the emergence of astronomy as an exact science from the old astrology, but it must be confessed that the Newton of meteorology has not yet appeared.

"Fifty years back the student of meteorology spent much of his time in a vain hunt for weather sequences, and the principle of *post hoc propter hoc* held full sway; the laws of motion and the more recently discovered laws of thermodynamics were in most cases completely ignored, or at least considered as not being applicable to meteorology. This has been largely changed for the better, and one does not now expect to find a cold area explained as being due to the descent of air in an anticlycone from a higher and colder region. Perhaps the pendulum has swung too far the other way, and mathematical analysis may sometimes be used when it is not applicable. On the assumption that air is a perfect fluid, it follows from a strictly mathematical analysis that a sphere exposed to a steady current of wind will offer no resistance to that wind, a result obviously inconsistent with the facts. The assumption made can not be justified, and one can not help feeling that great caution should be used in making assumptions if the result of a complex mathematical investigation into a meteorological question is to be trustworthy. Mathematics, however, afford a most useful and often indispensable aid to meteorology, and of late years especially, although far from exclusively, by their means many useful deductions have been drawn."

The remainder of the paper discusses recent advances in the study of cyclones and anticyclones, being essentially a summary of the material presented by the author in Geophysical Memoir No. 13,[1] an abstract of which, by Mr. W. R. Gregg, has been published in the MONTHLY WEATHER REVIEW.[2] After this discussion he concludes with the observation that "meteorologists have good cause for congratulation in the steady progress that is taking place."

[1] Dines, W. H.: Characteristics of the Free Atmosphere, Geophysical Memoirs, No. 13, Meteorological Office, London, 1919, M. O. 220c, pp. 47-76.
[2] Monthly Weather Review, September, 1919, pp. 644-647.

THE AMERICAN METEOROLOGICAL SOCIETY.

"The organization of the American Meteorological Society on December 29, 1919, in St. Louis, Mo. * * * marks the beginning of a movement not only to push forward investigations of weather processes and climatic conditions, but also to widen the valuable applications of the knowledge already at hand. The great use of meteorology in warfare has shown that there are large possibilities of extending it much more thoroughly into almost every line of human endeavor."[a] Significant of a recognition of this is the fact that nearly half of the present membership of nearly 600 is composed of people who find use for meteorology in their work, yet who are not professional meteorologists, or interested merely as amateurs.

The objects of the society as stated in the constitution are: "The advancement and diffusion of knowledge of meteorology, including climatology; and the development of its application to public health, agriculture, engineering, transportation by land and inland waterways, navigation of the air and oceans, and other forms of industry and commerce." To carry out these objects 11 committees have been formed; 4 to have in hand the advancement and diffusion of knowledge of meteorology, and 7 to have charge of the development of the numerous applications of meteorology to human affairs.

A total of 29 papers were presented at three sessions of the society in St. Louis, December 30 and 31, 1919, and in two sessions at a coordinate meeting in New York City January 3. Joint sessions were held with the American Physical Society and with the Association of American Geographers and National Council of Geography Teachers. In this issue of the REVIEW there are published five of these papers in full, extensive excerpts from

[a] Excerpt from the Bulletin of the Am. Meteorological Society, Jan., 1920, vol. 1.

three, and abstracts of 12. Abstracts of the most interesting discussions are included. The following nine are mentioned here by title only, for the reasons given:

Progress of American Meteorology in 1919. By C. F. Brooks. [The contributions in the REVIEW for the past 12 issues tell the story of this progress. This paper was founded on an article, "Meteorology and Climatology," in the American Year Book, 1919.]

How the American Meteorological Society can serve geography teachers. By C. F. Brooks. [Of limited interest.]

Aims and achievements of the Blue Hill Observatory. By Alexander McAdie. [To be published in full elsewhere. Not easily subject to abstracting.]

Plans for establishing a network of meteorological stations in Palestine. By P. W. Etkes, New York. [Simply a statement of plans.]

Sunshine in the United States. By R. DeC. Ward. [Published in the Nov. 1919, REVIEW, p. 794–795.]

Explanation of peculiarities of flying in the wind. By J. G. Coffin. [Published in Aviation, New York, Dec. 1, 1919, vol. 7, pp. 383–385.]

The following three are to be published in extended form in later issues of the REVIEW:

Use of laws in teaching climatology. By S. S. Visher.

Preliminary steps in making free-air pressure and wind charts. By C. L. Meisinger.

Clouds and their significance. By C. F. Brooks.

A BUNDLE OF METEOROLOGICAL PARADOXES.

By W. J. HUMPHREYS.

[Excerpts from presidential address, Washington Philosophical Society, Jan. 31, 1920; also, presented in part before American Meteorological Society, St. Louis, Mo., Dec. 30, 1919.]

The scientific paradox is only an exception to some familiar but too inclusive generalization. It therefore has both the appeal of the riddle and the charm of surprise—the suprise, the instant the truth is seen, of a sudden and unexpected discovery.

1. **Air pushed north blows east** (due to the deflective effect of the earth's rotation).

2. **Rain dries the air** (since rain is formed from water vapor previously existing in the air).

3. **More air goes up than ever comes down.**

As everyone knows, the vertical circulation of the atmosphere is only a gravitational phenomenon consisting of the sinking of relatively cold, and, therefore, also relatively dense air, and its consequent lifting or forcing up of adjacent air that happens to be comparatively warm and light. In short, contracted air descends and expanded air ascends (is buoyed up by the descending denser air). Hence, mass for mass, the *volume* of the ascending air is always larger than that of the descending air. The ratio between the actual ascending and descending volumes, however, or masses, may be anything, as illustrated by chimney circulation, in which the ascent is restricted to a comparatively small volume and mass moving rapidly, while the descend extends to a relatively large volume and mass settling slowly. On the average, though, considering both velocity of vertical movement and volume occupied, or velocity times volume, the atmosphere as a whole is always ascending, a fact not only interesting itself but also of some importance to both the aeronaut and the aviator.

Whatever the volume relations between ascending and descending air may be, it would seem that at least the mass that goes up and the mass that eventually returns must certainly be the same. But, on the contrary, they indeed are far from it, for one of the important constituents of the atmosphere, water vapor, often amounting, in places, to 1 per cent, and occasionally to more than 2 per cent of the whole, invariably ascends as a gas, as a distinct part and parcel of the air; but descends, in great measure, not as a gas at all, not as any part whatever of the air, but as a liquid in the form of rain, or a solid, such as snow and hail.

Paradoxical, therefore, as it may be, a greater mass of *air* actually does go up—more by at least 20,000,000 tons per second, the measure of world-wide precipitation—than ever comes down.

4. **To cool air, heat it; to warm air, cool it.** [Heated air rises and cools more than it was heated, and vice versa.]

5. **Not air that is heated, but air that is not heated, is thereby warmed; not air that is chilled, but air that is not chilled, is thereby cooled.** [Heated air rises and is replaced by other air which is dynamically heated in descent, and vice versa.]

6. **Mixing brings the air to a nonuniform temperature.** [When thoroughly mixed, the potential temperature of the air is the same; hence the temperature gradient is adiabatic and not isothermal.]

7. **The nearer the sun the colder the air.**

[The air grows colder with elevation—the nearer the sun the colder the air—because (1) owing to its transparency to solar radiation it is heated mainly at the surface of the earth, and (2) because, at ordinary temperatures, it emits more radiation than it absorbs. These together so affect the density of the atmosphere as to induce vertical convections, and thereby to establish and maintain, throughout the region in which they are active, a rapid decrease of temperature with increase of elevation.]

8. **The coldest air covers the warmest earth.** [Refers to the air in the stratosphere, which is coldest over the equator. The temperature of the stratosphere seems to depend upon radiation from below, and consequently upon the effective temperature of the earth's surface below; but the heavy cloudiness in equatorial regions makes the effective temperature of the surface there less than that at middle and high latitudes.]

9–10. **As the days grow longer the cold grows stronger; as the nights grow longer the heat grows stronger.** As the sun descends the temperature ascends. [Due to lag in heating and cooling the atmosphere.]

11. **The absolute maximum supply of heat in any consecutive 24 hours is not at the equator but at the south pole.** [As some one has remarked, "The sun shines day and night at the south pole." The south pole receives more insolation than the north pole, because the earth is nearest the sun when the south pole is best exposed to its rays. The altitude of the south polar region, the dryness of the air, and the lack of dust in the Antarctic atmosphere assist also.]

12. **The hotter the sun the colder the earth.** [Statistics show that at sun-spot maximum the earth is colder than at sun-spot minimum. At spot maxima there is less ozone produced in the upper atmosphere because the ultra-violet rays, which are the ozone-producing agents, are retained in the then dustier solar atmosphere. Hence at spot minima there will be more ozone in upper atmosphere of the earth. Ozone acts as a shield that decreases the radiation of heat from the earth, and thus keeps it warm, even though there is less total insolation.

13. **The sun rises before it is up; the sun sets after it is down** [due to the bending of the rays by refraction].

MOTION PICTURES OF WEATHER MAPS: A REPORT OF PROGRESS.[1]

By J. WARREN SMITH.

[Author's abstract.]

A project is well underway to illustrate the movement of storms and general weather conditions across the country by means of motion pictures.

Scenarios have been outlined to show: (1) The movement of a West Indian hurricane from the Atlantic into and across the Gulf of Meixco, its curving path onto the mainland and across the United States, and its movement across the Great Lakes and down the St. Lawrence to the North Atlantic; (2) the movement of cold waves; (3) heavy rainfall and floods; (4) heavy snowstorms; (5) local thunderstorms and tornadoes; and (6) comparisons of the climate of different sections of the country.

The movement of the hurricanes and of other weather conditions will be shown by weather maps drawn for each 15 minutes. Each map will be photographed from 6 to 48 times. Proper explanatory heads will be made and the weather maps will be accompanied by a suitable collection of motion pictures to illustrate the weather conditions and effects. These will consist in part of storm damage, waves on the coast, orchard heating, snow scenes, etc.

It is believed that these pictures will be of high educational value and show the work of the Weather Bureau and the marked value of its forecasts and warnings.

[1] Presented before the joint meeting of the Am. Meteorological Soc., Assoc. of Am. Geographers and Nat'l Council of Geog. Teachers, St. Louis, Mo., Dec. 31, 1919.

DETERMINATION OF THE NORMAL TEMPERATURE BY MEANS OF THE EQUATION OF THE SEASONAL TEMPERATURE VARIATION AND OF A MODIFIED THERMOGRAPH RECORD.[1]

By FRANK L. WEST, N. E. EDLEFSEN, and S. P. EWING.

[Utah Agricultural College, Logan, Utah.]

[From authors' abstract.]

The daily and annual march of normal temperature in the arid west may be approximated from a pair of formulas where bulky tables are not convenient.

The normal air temperature is a periodic function of the time, there being two prominent periods, a 24-hour and an annual period. The mean daily temperature for the different days of the year for Utah was plotted and the following empirical equation for the curve was obtained by the Fourier series:

$$T=48.5-22.2 \cos (\theta-19°54')-2.7 \cos 2 (\theta-149°5') -1.0 \cos 3 (\theta-17°3') \ldots .$$

in which T represents the mean annual temperature and θ the time expressed in degrees, e. g., April $1=90°$, July $1=180°$, etc. The same curve for widely separated places in the interior of the United States are nearly identical in shape, and, when superimposed on the curve for Utah, in the most extreme case, projected but 2 degrees above the maximum and 2 degrees below the minimum. The first term in the above equation is the mean annual temperature for the place considered, and simply displaces the curve up and down on the page, while the amplitude is determined by the difference in temperature between winter and summer, and varies in different places in the interior of the United States from the Utah value by from 1 to 4 degrees F. The above equation, therefore, is of general application.

The curve representing the diurnal temperature change modifies its shape gradually each day flattening out as winter approaches. We find that the daily variation in temperature is about twice as much in summer as in winter. However, the ratio of the hourly temperatures is nearly constant whatever day of the year is selected, e. g., the ratio of the maximum to the mean (on the Fahrenheit scale) is approximately a constant for all days of the year. The equation for this daily curve is as follows:

$$P=97.3-25.2 \cos (\theta-67°10')+3.7 \cos 2 (\theta-38°)- 1.5 \cos 3 (\theta-23°16') \ldots .$$

in which P represents in per cent of the mean daily temperature of the hour of which θ is the time of day expressed in degrees; e. g., 6 a. m. $=90°$, noon $=180°$, etc. This equation is also of general application. Using the above method, it is found that in the arid west the chances are one in six that the actual temperature will differ from the computed value by less than 2° F., two in five that it will be as large as 5° F., one in four that it will be as much as 10° F., and one in seven that it will be as much as 15° F. Cyclones and anticyclones are the main causes of these departures.

[1] Presented before Am. Meteorological Soc., St. Louis, Mo., Dec. 31, 1919.

DISCUSSION.

The discussion brought out clearly that although these formulas could be used to advantage in the absence of tables to compute probable temperatures on some future date, the results of such a computation would be in no sense a long-range forecast.

Dr. West called attention to the effect of the curved time lines on a thermograph sheet in making the afternoon decline of temperature appear much steeper than the morning rise, whereas for several hours on either side of the maximum the two are of practically the same order.

DR. JOHN AITKEN.[1]

The death of Dr. John Aitken, LL. D., F. R. S., on November 13 at the age of 80 is announced. Dr. Aitken was best known to meteorologists for his researches concerning dust particles in the atmosphere and their functions as nuclei of cloudy condensation, and for his theory of the formation of dew. His other investigations covered a wide field.—*Met'l Office Circular, Dec. 1, 1919, p. 4.*

Probably the name of John Aitken will be associated more particularly with the discovery of the place of dust in the functions of the atmosphere, and to the revision of the theory of dews, but his services to experimental meteorology are much more extensive. His valuable researches on the measurement of air temperature have never been fully appreciated by meteorologists and it is to be feared that they are little known. They deal almost exhaustively with the effect of radiation on thermometer bulbs of different size and surface, with the effect of shelter in thermometer screens, the influence of a current of air flowing over the bulbs, and the possibility of securing such a current by the use of a chimney of appropriate size and suitable surface. * * *

[1] A longer discussion of the life and work of Dr. John Aitken is to be found in *Nature* (London), Nov. 27, 1919, pp. 337-338.

To Dr. Aitken his researches were everything. He shrank from public appearances and had no ambition to take a leading part in the conduct of scientific societies. He was equally indifferent to the conventional opinions which dominate so many scientific workers, and cared little for scientific orthodoxy if the plain leading of observation and experiment ran athwart its canons.—*Extract from Symons's Met'l Magazine, Dec., 1919, pp. 125–126.*

COMPOSITION OF THE ATMOSPHERE OF THE SOIL.

[Reprinted from Scientific American, New York, Apr. 6, 1919, p. 428.]

From 10 to 20 per cent by volume of the soil is composed of air, but this "atmosphere of the soil" differs from the superficial atmosphere in composition and is likewise more variable. The percentages of its constituents vary likewise from season to season. Recent investigations of this subject by two English scientists, Messrs. Russel and Appleyard, at Rothamstead in England, furnish some interesting data. To a depth of 0.15 meter the soil atmosphere is very similar to that of ordinary air, though containing a litle more carbon dioxide, but the total amount of carbon dioxide plus oxygen is less than in the air. During periods of active nitrification the percentage of oxygen diminishes, and this is one of the conditions which characterizes the so-called "awakening" of the earth in spring.

Besides the atmosphere entangled in the interstices of the soil there is a certain amount of air dissolved in the water and the colloids the soil contains, but this is almost entirely deprived of oxygen.

From November to May the curves follow the temperature, but from May to November the percentage of oxygen in the atmosphere of the soil increases with every rainfall (as does bacterial activity), which proves that the soil-atmosphere is renewed by the rain. This fact indicates that rain is superior to irrigation. As might be expected, soil which is covered with turf contains more carbon dioxide and less oxygen than arable earth. The composition of the soil-atmosphere appears to be but slightly affected by variations in barometric pressure, by temperature, by velocity of the wind, or by crop conditions.

THE NITROGEN COMPOUNDS IN RAIN AND SNOW.

By F. T. SHUTT and R. L. DORRANCE.

[Reprinted from Science Abstracts, Sec. A, Feb. 28, 1919, Sec. 146.]

The paper summarizes the results of 10 years' work on the nitrogen compounds brought to the earth by rain and snow at a station near Ottawa. A total of 65.8 pounds of nitrogen per acre was furnished in this way in the 10 years, made up of 34.1 pounds in the form of free ammonia, 10.1 pounds of albuminoid ammonia, and 1.6 pounds of nitrates and nitrites. The rain was caught in a tray 60 inches by 30 inches. Every separate fall of rain of more than 0.01 inch was analyzed, while in the case of continuous precipitation measurements were made twice a day. During a period of severe drought when bush fires were prevalent in the neighborhood the scanty rain was particularly rich in free ammonia. Rain was found on the average to be approximately twice as rich as snow in nitrogen compounds, but the individual samples showed more variability with rain than with snow.

THE ROARING OF THE MOUNTAIN AND ASSOCIATED PHENOMENA.[1]

By W. J. HUMPHREYS.

[Author's abstract.]

In many mountainous regions it is a common thing to refer to the "roaring" of the mountain as a sign of a general storm, within 6 to 24 hours, and the "sign" is a good one.

In the Alleghenies, for instance, where the general trend of the ridges is northeast to southwest, an approaching cyclone very often causes the winds to blow across the crests from the southeast, or in such direction as to bring precipitation. In such cases noises on the windward side of a mountain are often distinctly heard in the leeward valley where at other times they are quite inaudible; the sighing of the wind among the trees on the top is roughly focused by the wind also onto this valley, and merged into a cataract roar; the crest is soon mantled with cloud; a separate cloud billow parallels the mountain over the valley; and the winds beat strongly on a relatively narrow belt near or beyond the foot of the mountain. After a shorter or longer interval, the crest cloud thickens, the sky becomes covered throughout, and the precipitation begins. Such is the typical course of events when the mountain roars—all interesting and all explainable.

[1] Presented before the American Meteorological Society, St. Louis, Dec. 30, 1919.

SOME APPLICATIONS OF RADIOTELEGRAPHY TO METEOROLOGY.[1]

By Prof. J. C. JENSEN, Nebraska Wesleyan University.

[Author's abstract.]

It is the experience of every radio operator that his efficiency in receiving will be much lessened during the summer months because of ever-present static interference. Observations extending over several seasons in the writer's station, 9YD, show that there is a definite relation between the radio transparency and amount of static disturbance of the atmosphere and the distance and violence of an approaching storm. This is peculiarly true of local thunderstorms which have always proved difficult for the forecaster. This suggests the desirability of concerted action for the simultaneous observation of storms as they pass a given region, along the lines proposed in antebellum days by the British Association for the Advancement of Science. A series of radio stations associated with the Weather Bureau would also be of great value both in gathering additional data during the day and in sending out storm and cold-wave warnings.

DISCUSSION.

Mr. J. P. Henderson remarked that the times of maximum static seems to be different in different parts of the world.

Prof. Jensen stated that the maximum static occurs at twilight, and with a falling barometer. It is at least on clear days following a LOW.

Lieut. Keyser asked if static was more troublesome in summer than winter.

Prof. Jensen replied in the affirmative, and also noted that it was greater in cloudy weather, and in tropical regions.

Lieut. Keyser remarked that radio-directional apparatus had been used to locate thunderstorms.

[1] Presented before the American Meteorological Society, St. Louis, Mo., Dec. 30, 1919.

ELECTRICAL PHENOMENA IN THE UPPER ATMOSPHERE.

By S. CHAPMAN.

[Abstracted from *Scientific American Supplement*, Sept. 27, 1919, p. 198, and Nov. 29, 1919, p. 323. See also note in *Nature* (London) June 19, 1919, p. 311.]

The electrical phenomena discussed in the paper are those arising in regions of the atmosphere at altitudes probably greater than 30 kilometers, as distinct from the ordinarily investigated phenomena of atmospheric electricity, which are confined to the troposphere and lower parts of the stratosphere.

Electrical phenomena in the upper atmosphere make themselves evident in two ways—by the production of luminosity, as in the case of the aurora, and by the variations which they cause in the earth's magnetic field. Auroral phenomena result from the injection, into the earth's atmosphere, of corpuscular radiations from the sun, the effects being associated, in large part, with particular regions of the sun's surface, e. g., sun spots. The sharp lower boundary frequently associated with auroral displays suggests a definite degree of penetration for the rays; and, the definiteness and magnitude of this penetration is well in harmony with the assumption that the rays are α rays. The assumption is further borne out by considerations of the magnitudes of the deflections which the rays must suffer, on account of their motion in the earth's magnetic field, in order to account for a radius of the auroral zones as large as 20 degrees, which is the radius found by actual measurement, and which is considerably greater than could be accounted for on the assumption that the radiation was of the β ray type.

As regards magnetic phenomena, there is a direct part, arising from currents induced in the upper atmosphere, and an indirect part arising from the currents which these induce in the earth. The atmospheric currents are of two types—those associated with magnetically quiet days, and those productive of magnetic storms. The former result from the electromotive forces induced in the upper atmosphere, as a result of its motion in the earth's magnetic field, under atmospheric tidal action, and under the influence of temperature variations produced by the sun. The currents induced depend not merely upon the electromotive forces, but also upon the conductivity of the upper atmosphere itself. The latter is greater in the sun-lit portions than elsewhere, so that, superposed on the diurnal and seasonal variations which the tidal motion would produce, we have the changes arising from variations in the solar radiation received throughout the day and year. Considerations of the amount of ionization necessary to account for the effects, and of the degree of penetration which the radiation must have to enable it to escape from the sun's atmosphere, suggest that the radiation effective in this process is of the γ ray type.

Disturbances of the magnetic-storm type are attributed to effects arising from the penetration of the outer layers of our atmosphere by the α rays responsible for the aurora. The view is expressed that, as the α rays enter the atmosphere, they cause a depression of the air as a result of loss of their momentum, and that this depression is followed by an upward motion resulting from electrostatic repulsion after the air has become charged. The downward motion of the air accompanying the depression, and the subsequent upward motion, both taking place across the earth's lines of magnetic force, give rise to induced currents; and, it is assumed that the magnetic fields of these induced currents are those which are found associated with so-called magnetic storms. The view adopted accounts for the reversal of the magnetic effect, which is found to take place soon after the commencement of a magnetic storm.—*W. F. G. Swann.*

CLOUDINESS IN THE UNITED STATES.[1]

By Prof. R. DEC. WARD, Harvard University.

[Author's abstract.]

The available cloudiness charts include those of Teisserenc de Bort (1884), Greely (1891), Clark (1911), and Gläser (1912). Gläser has made the most complete study of the cloudiness and sunshine of the United States to date. A new chart of mean annual cloudiness is presented, based upon the latest and most complete data now available. These were prepared for the author by the U. S. Weather Bureau, and include observations through the year 1918. The new chart is broadly generalized, being designed to present the larger facts, and not to emphasize details. The distribution of mean annual cloudiness is described and explained, and the seasonal variations in cloudiness are considered. A series of curves is given showing the monthly amounts of cloudiness at groups of selected stations in various parts of the United States.

[1] Presented before American Meteorological Society, New York City, Jan. 3, 1920, to appear in *Geogr. Rev.*, 1919, vol. 8.

THERMAL BELTS AND INVERSIONS OF TEMPERATURE IN THE NORTH CAROLINA MOUNTAIN REGION.[1]

By H. J. COX.

[Author's abstract.]

Observations were made by the U. S. Weather Bureau in the North Carolina mountain region from 1912 to 1916, inclusive, in cooperation with the North Carolina State Board of Agriculture, with the hope that so-called "thermal belts" might be more clearly defined.

Stations were installed at 16 places in the mountain region, distributed geographically and under varying conditions of topography, on valley floor, slope, and summit, there being 66 stations in all.

Inversion of temperature was observed on an average of three nights out of four, and the tendency toward inversion was so strong that the average minimum for the four-year period was found to be much higher at the summits than on the valley floor, and even at one place where the slope had a vertical height of 1,760 feet, this was true. Frequently inversions of 15 to 20 degrees F. were observed. The greatest was 31 degrees F. on Brown Mountain November 13, 1913, for a difference of elevation of 1,000 feet.

Inversions were noted under both anticyclonic and cyclonic conditions, in the latter case the temperature rising much more rapidly at the summit than at the base as the storm approached, warm winds of the lower levels being shut off by obstructing mountains and the cold air in the coves and valleys lower down being retained.

On the longest individual slope, 1,760 feet, the center of the thermal belt was usually at a point 1,200 to 1,300 feet above the valley floor, while on all short slopes (less than 1,100 feet) leading up to knobs, the highest minima were observed on the knobs themselves on radiation nights.

[1] Presented before joint meeting of Am. Meteorological Soc. and Assoc. of Am. Geographers, St. Louis, Mo., Dec. 31, 1919.

The minimum is always comparatively low on radiation nights where there is little if any warm free air available for interchange. This condition is most pronounced on the valley floor, but also quite evident in a sheltered cove, even though located on a slope. For the same reason the minima are lower on gradual slopes than on steep slopes, a given area on the latter having a much larger amount of warm free air facing it and at the same time not being so freely exposed to the sky as to suffer the same loss through radiation as the gentle slope.

When a slope has opposing mountains close by, the minima are lower, even though these mountains, in raising the sky line, affect the loss of heat through radiation.

Although the summit of a mountain is usually situated ideally for radiation purposes, the highest minimum is, nevertheless, noted at the very summit during inversion conditions, except when either its surroundings mass is great or its vertical height is great, a knob partaking largely of the temperature of the free air.

Where the mass is great a large number of radiating surfaces are present, which serve to reduce the temperature to a greater degree than if the summit were a mere knob, and in lowering the temperature in the vicinity of the summit the center of the thermal belt is also lowered.

The center of a thermal belt is lowest on a mountain slope where there is no opposing slope near by and the mass above in the region of the summit is great. The Tryon slope is a typical example of this condition, where the highest minimum is usually found at an altitude of 400 to 500 feet above the valley floor, there often being differences of 15 to 20 degrees F. between these points separated by only a few hundred feet.

On the other hand, the center of the thermal belt is high when the slope culminates in a knob, so that there is no considerable mass near the summit, and this is so whether there are opposing slopes or not.

When opposing slopes are present in the lower levels and there is a great mass above near the summit, the thermal belt is relatively narrow, as both these conditions tend toward lower night temperatures. Such a slope, as a whole, is a cold one. If, on the other hand, a slope is steep and there are no opposing slopes near by and no great mass near the summit, the entire side of the mountain is relatively warm during night inversions.

The temperature, ordinarily, on a night of inversion falls along the entire slope, as well as on the valley floor, but with increased elevation the fall is less and less, and the center of the belt rises steadily from nightfall to dawn.

Mountain breezes do not blow down the sides of a mountain from a mere knob, but where the mass is great, as at Altapass on the main Blue Ridge, or at Tryon, the breeze is frequently observed. The mass being freely exposed with its great surface, in fact an elevated plateau, becomes covered with a blanket of cold air on radiation nights and, if the prevailing wind is favorable, after a time this cold air rushes down the side of a mountain in a more or less waterlike flow, being mechanically warmed in its descent, but nevertheless serving to lower the temperature, at least for a time, on the slope, while raising it in the valley below where the temperature has already fallen to a low point. If the wind is blowing from an unfavorable quarter, the mountain breeze does not develop, even though other favorable conditions are present.

Inversions are most frequent during the months of May and November, when the weather conditions are usually settled in the mountain region, long periods of fair weather then prevailing. They are somewhat more pronounced in the latter month because of the greater length of the night, the thermal belt rising as the length of night increases.

Inversions are almost as frequent during the summer months, but the range is small. In the winter months, when they are much less frequent, the range is great. During a period of fair weather the range of inversion increases steadily up to about the fifth night, the peak being reached at that time. Thereafter increasing vapor and impurities in the form of dust and smoke interfere with radiation. The range of inversion depends decidedly upon relative and absolute humidity. The vapor pressure controls the degree of inversion in that the loss of heat by radiation through moist air is small, while through dry air it is large.

The lowest absolute and average minima during the entire research were found in a small frost pocket at Highlands, but the lowest minimum considering altitude above sea level was found in a wide valley floor of the French Broad River near Blantyre.

The higher temperatures on the slopes and certain summits in the Carolina mountain region are favorable for fruit growing in so far as the absence of frost is concerned, as compared with the valley floors, but considerable injury often occurs from freezes in the winter and early spring in the upper and middle levels after protracted heated periods and growing weather which had served to swell the buds.

THE EFFECT OF A "LID" ON THE TEMPERATURE AND TRANSPARENCY OF THE LOWER AIR.[1]

By JACQUES W. REDWAY, Mount Vernon, N. Y.

The word "lid" was coined by Sir Napier Shaw to describe a condition in the lower atmosphere in which a warm layer overlying a cooler one acts as a limiting plane or lid to the convectional circulation of the underlying air. If the warm layer is in motion relative to the air below, as it usually is, the lid may be turbulent. The convectional currents of warm more or less hazy air rising from the surface stop and spread horizontally on reaching the lid. Thus, the haziness is confined and the amount of air to be warmed by the earth's surface is limited. When the haziness is largely due to smoke, the aviator is more concerned than the mariner, for the air is clearest near the earth's surface; but when the haziness is due mostly to moisture conditions of the air, the haze is likely to be densest at the earth's surface, unless clouds tend to form at the lid. The presence of a lid makes the temperature at Mount Vernon about the same as that in New York City (Whitehall Building). Without a lid, however, the range at Mount Vernon is several degrees greater than at New York.—*C. F. B.*

[1] Presented before the American Meteorological Society at New York Jan. 3, 1920. This paper is a rearrangement of a part of a chapter on the "Principles of the transparency of the air governing visibility," in one of the author's books.

DYNAMICAL METEOROLOGY.[1]

By FELIX M. EXNER.

[Review.]

This work is essentially a mathematical discussion of certain phenomena mainly connected with movements of the air. As it treats with only selected portions of meteorology it is not a general text book. While it is far from easy reading, nevertheless, it is well worth while for the mathematically inclined. One particularly interesting section deals with the rate of temperature decrease with altitude of an adiabatically rising mass of air through an atmosphere whose gradient is "non-adiabatic."—*W. J. H.*

DUST STORM AT SALT LAKE CITY APRIL 4, 1919.

The Deseret News, April 5, 1919, of Salt Lake City, Utah, reports a storm of alkaline dust, which covered a large portion of Utah on April 4, 1919. This storm was preceded by a shift of the wind from south to northwest, with a wind of gale force, and was accompanied by rather violent fluctuations of the barometer. The cloud bearing the dust was black and appeared to extend a great distance to the north and south, as seen from Salt Lake City. Rain fell as the dust hung over the city, resulting in considerable inconvenience from bespattered windows, automobiles, etc. The mud was of distinctly salty taste, and many thought that it was salt from the Great Salt Lake; but it was simply desert mud containing a high percentage of salts.

DUST STORM AT PORTLAND, OREG., SEPTEMBER 27, 1919.

The following is the report of an unusual deposit of mud which occurred at Portland, Oreg., on September 27, 1919:

The particles were brought down in suspension in rain-drops, the rain continuing for about two and one-half hours. The quantity was sufficient to make a thin coating over all exposed objects. When dry it was of gray color, and resembled fine, light, decomposed lava soil, such as is found over large areas in the intermountain region.

There had been no dust storms in this vicinity, but reports from the interior of the State indicated that the air had been very dusty for several days. Passengers arriving on the Oregon-Washington Railway & Navigation Co. train on the 28th reported the most dusty trip ever experienced. Cooperative observers report an unusually dusty condition as follows: Milton, 29th; Pendleton, 27th; Pilot Rock, 28th; Prairie City, 27th–28th; Riverside, 27th–30th; Umatilla, 27th.

The deposit of mud seems to have been confined to a small area in the vicinity of Portland and up the Columbia River toward Cascade Locks. Apparently the dust had been carried by wind through the Columbia Gorge, and had not spread over a wide area west of the Cascades.

The cooperative observer at Dayville writes as follows: "Your city was not the only place the dust fell, for it covered and penetrated everything, even to the inside of our piano. It is impossible it could have come from summer fallow, in fact it hadn't the appearance of that kind of dust, but more nearly approaching the color of pumice, it hung over this section of country for two days."—*Edward L. Wells.*

[1] Dynamische Meteorologie. Leipzig. 1917. ix, 308 p., charts, diagrs. 23 cm.

DIFFICULTIES IN THE THEORY OF RAIN FORMATION.[1]

By W. J. HUMPHREYS.

[Author's abstract.]

The formation of raindrops has never been satisfactorily explained. The general assumptions seem to be (1) that as soon as saturation is passed, condensation occurs on the nuclei present; (2) that the larger droplets, owing to their lesser vapor tension, grow at the expense of the smaller; and (3) that the larger and faster falling droplets unite with enough others on their downward path to form full-sized raindrops.

All this sounds very plausible, but it will not stand analysis. It is true that as the temperature falls below the dew point, condensation does occur on the dust particles and any other nuclei that may be present. But this at once introduces a formidable difficulty; that is, the number of such particles is so great that even all the water present could not develop them to a "falling" size. It is also true that the larger drops do grow at the expense of the smaller, but, according to theory, at a rate far too slow to be effective in the process of rain production. Finally, even if a droplet should fall quite through a cloud layer, and actually coalesce with all particles in its path, the chance of its thus becoming a full-sized raindrop would be very small.

The chief steps in rain formation seem to be (*a*) the continuous ascent of humid air; (*b*) the formation of cloud droplets on the nuclei of this air as soon as it cools below the dew point; (*c*) the filtering by these droplets of the next rising air; (*d*) the progressive condensation, in the midst of the rain cloud, on the relatively few droplets present in this automatically filtered air, and their consequent growth to "falling" size; (*e*) coalescence with other droplets, facilitated by such electrical changes as they may have—and they are nearly always charged.

[1] Presented before the joint meeting of the American Physical Society and American Meteorological Society, St. Louis, Dec. 30, 1919.

EVIDENCE OF CLIMATIC EFFECT IN THE ANNUAL RINGS OF TREES.[1]

By Prof. A. E. DOUGLASS, University of Arizona.

[Author's abstract.]

The rings of the yellow pine in northern Arizona show varying thickness in marked correlation with rainfall. The sequoias of California show similar characteristics. In less degree climatic effects may also be detected by finding similarity in ring growth of trees over large areas.

DISCUSSION.

Prof. H. J. Cox had noted a waxy deposit on the leaves of trees in Montana during a drought, and asked if this was the case in Arizona.

Prof. Douglass replied that this is a general characteristic of vegetation in the Southwest.

Prof. W. J. Humphreys asked if the cliff dwellings in Arizona can be dated by getting the age of the timber used in them.

Prof. Douglass answered that this probably could be done. He called attention also to the fact that in wet regions the rings show a very evident relation to solar radiation through sun-spot numbers, but that in dry regions the rainfall is a much more obvious cause of variations in the rings of trees.

[1] Presented before American Meteorological Society, St. Louis, Mo., Dec. 30, 1919. See "Climatic cycles and tree-growth. A study of the annual rings of trees in relation to climate and solar activity." Carnegie Institution of Washington, D.C., 1919. 127 p. illus. plates. 26cm.

BIBLIOGRAPHY.

RECENT ADDITIONS TO THE WEATHER BUREAU LIBRARY

C. FITZHUGH TALMAN, Professor in Charge of Library.

The following have been selected from among the titles of books recently received as representing those most likely to be useful to Weather Bureau officials in their meteorological work and studies:

Alciatore, H. F.

City endowed with matchless year-round climate . . . [San Diego, California]. (Cutting from San Diego Union, January 1, 1920. P. 2.)

Blomquist, Edv.

Mesures de l'évaporation dans le Pyhäjärvi près de Tammerfors en 1912 et 1913. Helsingfors, Bureau hydrographique, 1917. 120 p. illus., plates. 25cm.

Bouches-du-Rhône. Commission de météorologie.

Bulletin annuel. Année 1918. 37e année. Marseille. 1919. xii, 74, xxi p. map. fold. chart. tables. 28½cm.

Brown, C. H.

Meteorology for masters and mates, being questions and answers based on the information contained in the "Barometer manual" and "Seaman's handbook of meteorology." 4th ed. Glasgow. James Brown & son. 1919. 96 p. diagrs. 22cm.

Burns, G. P.

Weather conditions and plant development. (Photographed from Brooklyn botanic garden. Memoirs. Vol. 1. Brooklyn, 1918. p. 119–122.) 28cm.

Dorno, C. W. M.

Physik der Sonnen- und Himmelsstrahlung. (Repr. "Strahlentherapie." Vols. 9 and 10, 1919.) 557 p. tables. 24½cm.

Douglass, A. E.

Climatic cycles and tree-growth. A study of the annual rings of trees in relation to climate and solar activity. Washington, D. C. Carnegie institution of Washington, D. C. 1919. 127 p. illus. plates. 26cm. [See p. 881, above.]

Eredia, Filippo.

Le previsioni del tempo e la navigazione aerea. Roma. Giovanni Bardi. 1919. 8 p. 23cm. (Estratto dalla revista L'aeronauta, anno 2, n. 6–9, giugno-settembre, 1919.

La temperatura dell'aria e le precipitazioni dell'oasi di Zanzur (Tripolitania). Roma. Reale società geografica italiana. 1919. 8 p. tables. 23½cm. (Estratto dal Bollettino della Reale società geografica italiana. Fasc. 5–6, 1919, p. 361–366.)

La variazione della quantità di pioggia con l'altitudine. (Excerpted from Annali. Consiglio superiore delle acque pubbliche. Roma. 1919. Fasc. 1–6, p. 69–73.)

France. Service météorologique militaire.

Organisation et fonctionnement des postes météorologiques de renseignements. Paris. 1919. 44 p. 22cm.

Gallé, P. H.

Cyclonen in de Arabische Zee. Utrecht. Kemink & Zoon. 1916. 20 p. fold. charts. tables. 24½cm. (Koninklijk nederlandsch meteorologisch instituut. no. 102. Mededeelingen en verhandelingen. 21.)

Giandotti, Mario.

Boschi e acque. Roma. Ufficio idrografico del Po. 1918. 237 p. plates. diagrs. 23½cm.

Il fenomeno dell'accumulamento e della fusione delle nevi in relazione al regime degli afflusi. Parma. Ufficio idrografico del Po. 1919. 19 p. tables. diagrs. 28cm. (Dall'Italia elettrica. maggio 1919.)

Hartman, C. M. A.

Het klimaat van Nederland. B. Luchttemperatuur. Utrecht. K. Nederlandsch meteorologisch instituut. 1918. 104 p. tables. 24½cm. [Text also given in French, with title: Le climat des Pays-Bas. B. Température de l'air.]

Horner, D. W.

Meteorology for all, being some weather problems explained. With an introduction by M. de Carle S. Salter. London Witherby & co. 1919. xvi, 184 p. front. illus. plates. charts. tables. 19cm.

Howard, Albert.

The influence of the weather on the yield of wheat. Calcutta. Thacker, Spink & co. 1916. 2 tables. 25cm. (Repr. from the Agricultural journal of India. Vol. 2, part 4. October, 1916. p. 351–359.)

India. Meteorological department.

Report on the administration of the Meteorological department in 1918–19. Simla. 1919. cover-title. 14 p. chart. tables. 33½cm.

Johnston, E. S.

An index of hardiness in peach buds. 2 tables. 2 graphs. 26cm. (Excerpted from the American journal of botany. Brooklyn botanic garden. N. Y. Vol. 6, no. 9. Nov. 1919. p. 373–379.)

"Kalb Siad."

The occurrence and paths of storms and the method of avoiding damage from them. An essay on the occurrence and paths of those storms known as "Cyclones," as they are encountered in Eastern Seas between Aden and Singapore; including . . . Mauritius and . . . Indian Ocean between Mauritius and India. London. J. D. Potter. 1917. 18 p. 25cm.

Krogh, August.

The composition of the atmosphere. An account of preliminary investigations and a program. København. Andr. Fred. Høst & Søn. 1919. 19 p. illus. 24cm. [At head of title: Det Kgl. Danske, videnskabernes selskab. Mathematisk-fysiske meddelelser. I, 12.]

Mead, D. W.

Hydrology: The fundamental basis of hydraulic engineering. New York. McGraw-Hill book co. [etc., etc.]. 1919. xi, 647 p. front. illus. maps. charts. tables. 23½cm. ["Literature," given at the end of each chapter.]

Norway. Norske meteorologiske institut.

Nedbøriagttagelser i Norge. Aargang 24, 1918. Kristiania, 1918. 23cm.

Philippi, H.

Davos: historisches, klimatologisches und medizinisches. Davos. Engadine press co. 1919. 43 p. 22½cm.

Schrötter, Hermann v.

Der gegenwärtige Stand der Heliotherapie der Tuberkulose. Berlin-Charlottenburg. Internat. Verein. Tuberkulose. Kommissions-Berichte. 1912. 169 p. 23 cm. [Includes discussion of climatological factors.]

Sierp, Hermann.

Über die Lichtquellen bei pflanzenphysiologischen Versuchen. Leipzig, Georg Thieme. 1918. 257 p. tables. diagrs. 23cm. [Includes a discussion of daylight.]

Sverdrup, H. U.

Der nordatlantische Passat. Leipzig, Geophysikalisches Institut der Universität Leipzig. 1917. 96 p. charts. plates. 25cm.

Sweden. Hydrografiska byrån.

Arsberättelse for 1918. Stockholm. 1919. 42 p. tables. 31cm.

Sweden. Hydrografiska byrån.

Arsbok 8 för 1916. . . Stockholm. 1919. vi [1] 234 p. fold. map. charts. tables. 31½cm.

Terada, Torahiko.

On the effect of topography on the precipitation in Japan. (Contribution III, from the Geophysical seminary in the Physical institute, College of science) Tokyo. Imperial university College of science. 1919. 24. p. tables. diagrs. 26cm. [Journal of the College of science. Imperial universit of Tokyo. June 13, 1919. Vol. 41. Art. 5.]

RECENT PAPERS BEARING ON METEOROLOGY AND SEISMOLOGY.

C. F. TALMAN, Professor in Charge of Library.

The following titles have been selected from the contents of the periodicals and serials recently received in the Library of the Weather Bureau. The titles selected are of papers and other communications bearing on meteorology and cognate branches of science. This is not a complete index of all the journals from which it has been compiled. It shows only the articles that appear to the compiler likely to be of particular interest in connection with the work of the Weather Bureau.

Aeronautics. London. v. 17. December 25, 1919.
"Meteor." Weather and aviation. p. 585–586. [Continuation.]

Astrophysical journal. Chicago. v. 50. October, 1919.
Polarization of the night sky. p. 227–228.
Babcock, Harold D. Note on the polarization of the night sky. p. 229–231.

Franklin institute. Journal. Philadelphia. v. 189. January, 1920.
Humphreys, W[illiam] J[ackson]. Factors of climatic control. p. 63–98. [Conclusion of Physics of the Air.]

London, Edinburgh, and Dublin philosophical magazine. London. v. 38. December, 1919.
Lindemann, F. A. Note on the theory of magnetic storms. p. 669–684.

Science. New York. v. 50. December 26, 1919.
Price, W. Armstrong. Snow doughnuts. p. 591–592. [Describes a formation akin to snow-rollers.]

Scientific American. New York. v. 122. January 24, 1920.
The unpopular weather man. p. 84. [Editorial in defense of the Weather Bureau.]

Scottish meteorological society. Edinburgh. v. 18. 1919.
Gold, E. Meteorology and aviation. p. 68–76.
Franklin, T. Bedford. Meteorology and agriculture. p. 76–83.
Douglas, C. K. M. Optical phenomena and the composition of clouds. p. 83–86.
Wedderburn, E. M. Meteorology and gunnery. p. 86–92. [Brief review, this issue of the REVIEW, p. 869.]

Seismological society of America. Bulletin. v. 9. September, 1919.
Smith Warren Du Pré. Earthquakes in Oregon. p. 59–71.
Townley, Sydney D. Earthquakes on the Pacific coast of North America. p. 72–85.

Symons's meteorological magazine. London. v. 54. December, 1919.
M[ill], H[ugh] R[obert]. John Aitken, LL.D., F. R. S. Falkirk, 1839—13th November, 1919. p. 125–127. [See p. 877–878 this issue of the REVIEW.]
Douglas, C. K. M. The use of aeroplanes in meteorology. p. 127–130; 145–148.

France. Académie des sciences. Comptes rendus. Tome 169. 1919.
Soreau, Rodolphe. Lois expérimentales des variations de la pression barométrique et du poids spécifique de l'air avec l'altitude. p. 1023–1025. (1er déc.)
Fouché, Ed. Recherche d'une équation caractéristique appropriée à l'air atmosphérique. p. 1089–1092. (8 déc.)
Mesnard, Eugène. Les formations cycloniques de l'atmosphère. p. 1098–1101. (8 déc.)
Descombes, Paul. Sur le concours des arbres pour soutirer de l'eau à l'atmosphere. p. 1106–1108. (8 déc.)
Maurain, Ch. Sur la vitesse du vent dans la stratosphère. p. 1419–1420. (29 déc.)

France. Académie des sciences. Comptes rendus. Tome 169. 1919—Continued.
Stapfer, & Moleski. Remarques sur les chutes de neige. p. 1420–1422. (29 déc.)

Meteorologische Zeitschrift. Braunschweig. Band 36. 1919.
Dorno, C. Himmelshelligkeit, Himmelspolarisation und Sonnenintensität in Davos (1911 bis 1918). p. 109–124. (Mai/Juni.)
Kassner, C[arl]. Über sehr dichte Regenfälle. p. 125–132. (Mai/Juni.)
Paschinger, V. Beiträge zur Klimatologie des Steinfeldes. p. 133–137. (Mai/Juni.)
Barschall, H. Über die Gebirgswinde in den mittleren Vogesen. p. 137–142. (Mai/Juni.)
Linke, Franz. Die Grundgleichungen der polytropen Atmosphäre. p. 142–145. (Mai/Juni.)
Würschmidt, J[oseph]. Darstellung des mittleren täglichen Temperaturganges durch Fouriersche Reihen. p. 145–148. (Mai/Juni.)
Eine Widmung zu Julius von Hanns 80. Geburtstage. p. 149–151. (Mai/Juni.)
Schreiber, P[aul]. Ein Jahr Messungen mit dem Michelsonschen Bimetallaktinometer an der sächsischen Wetterwarte Wahnsdorf bei Dresden. p. 151–153. (Mai/Juni.)
Defant, A[lbert] A. Ångström, Strahlung und Temperatur des Schnees und die Konvektion der Luft an seiner Oberfläche. p. 153–155. (Mai/Juni.)
Grosse. Dampfdruck und relative Feuchtigkeit in graphischer Darstellung. p. 155–157. (Mai/Juni.)
Göschl, Fr[anz]. Die 3.2 monatliche Schwankung in den Monatsmitteln der Niederschläge in Salzburg. p. 157–158. (Mai/Juni.)
Conrad, V[ictor]. Zur Berechnung höherer Glieder der Fourierschen Reihe. p. 160. (Mai/Juni.)
Galbas, P. A. Bedingungen, die bei der Wahl eines Ortes für ein aërologisches Observatorium zu stellen sind. p. 165–166. (Mai/Juni.)
Kerner, Fritz v. Eine neue Schätzung des Gesamtniederschlages auf dem Meere. p. 167–168. (Mai/Juni.)
Hann, J[ulius] v. G. Hellmann, Über abnorme Winter und Sommer in Berlin seit 1766. p. 173–180. (Juli/Aug.)
Dorno, C. Himmelshelligkeit, Himmelspolarisation und Sonnenintensität in Davos (1911 bis 1918). (Juli/Aug.) Conclusion.
Georgii, Walter. Sciroccobeobachtungen im südwestlichen Teile Palästinas. p. 193–197. (Juli/Aug.)
Forch, Carl. Temperaturen der freien Atmosphäre über der südungarischen Tiefebene. p. 197–202. (Juli/Aug.)
Kühl, A. Die Beaufortskala als Empfindungsgesetz. p. 202–207. (Juli/Aug.)
Schmauss, A[ugust]. Randbemerkungen III. p. 207–212. (Juli/Aug.)
Hergesell, H[ugo]. Der tägliche Gang des Luftdruckes und der Temperatur in der freien Atmosphäre. p. 212–217. (Juli/Aug.)
Hann, J[ulius] v. Über die Abnahme der Amplitude der halbtägigen Druckwelle mit der Höhe. p. 218–219. (Juli/Aug.)
Koppen, W[ladimir]. Vorhersage des Wetters. p. 221–223. (Juli/Aug.)
Schmidt, Wilhelm. Sind die überadiabatischen Gradienten reell? p. 223–225. (Juli/Aug.)
Hann, J[ulius] v. Zur Meteorologie der Süd-Orkney-Inseln. p. 225–227. (Juli/Aug.)
Gautier, F. Die Temperaturverhältnisse von Karlsruhe i. B. auf Grundlage längjähriger Beobachtungen. p. 228–230. (Juli/Aug.)
Sassenfeld, Max. Zur täglichen Periode der Sommerregen, insbesondere der Platzregen. p. 231–233. (Juli/Aug.)

Hemel en dampkring. Den Haag. 17 jaarg. Nov. 1919.
Mulder, M. E. Verklaring van de wijze van orienteering van in onze atmospheer vallende of zich voortbewegend voorwerpen. p. 97–101.

SPECIAL OBSERVATIONS.

SOLAR AND SKY RADIATION MEASUREMENTS DURING DECEMBER, 1919.

By HERBERT H. KIMBALL, Professor of Meteorology.

[Dated: Solar Radiation Investigations Section, Washington, Jan. 29, 1920.]

For a description of instrumental exposures, and an account of the methods of obtaining and reducing the measurements, the reader is referred to the REVIEW for January, 1919, 47:4.

The monthly means and departures from normal in Table 1 show that radiation measurements averaged very close to December normal values at all stations.

Table 3 shows a deficiency in the total radiation for December at Washington of about 4 per cent, and an excess at Madison and Lincoln of 7 per cent and 2 per cent, respectively. It will be noted from the table that all three stations show a deficiency of radiation for the year, ranging from 3 per cent at Lincoln to 6 per cent at Washington.

The skylight polarization measurements made at Washington on 4 days give a mean of 62 per cent, with a maximum of 66 per cent on the 3d. These are average values for Washington in December. No polarization measurements were obtained at Madison, as the ground was covered with snow throughout the month.

TABLE 1.—*Solar radiation intensities during December, 1919.*

[Gram-calories per minute per square centimeter of normal surface.]

WASHINGTON, D. C.

Date.	Sun's zenith distance. 0.0°	48.3°	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°
	Air mass. 1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
A. M.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.
Dec. 1			1.27							
3	[1] 1.56		1.42	1.33	1.24	1.15	1.08	1.05	1.02	0.96
4			1.13	1.04	0.93	0.84	0.76	0.69		
11			1.14	1.07	1.01	0.95	0.90	0.84	0.80	0.75
15					1.16	1.09	1.02	0.92	0.87	0.82
16			1.14	1.11	1.01	0.94	0.87	0.81	0.75	0.69
20				1.03						
21			0.94							
22			1.17							
30				1.01			0.76	0.72		
31				1.05	0.95	0.93		0.81	0.78	
Monthly means			**1.17**	**1.09**	**1.05**	**0.98**	**0.90**	**0.83**	**0.84**	**0.80**
Departure from 12-year normal			**−0.05**	**−0.03**	**±0.00**	**±0.00**	**+0.01**	**+0.02**	**+0.08**	**+0.14**
P. M.										
Dec. 1				1.19	1.13	1.05	0.99	0.93	0.87	0.83
3				1.30	1.20	1.12	1.04	0.99	0.95	0.91
4				1.02	0.93	0.86	0.79	0.65	0.58	0.53
10					1.06	0.94	0.92	0.80	0.76	0.72
21				0.83	0.76	0.68		0.61	0.57	
22				1.13	0.98	0.88	0.80	0.73	0.67	
Monthly means				**1.09**	**1.01**	**0.92**	**0.91**	**0.78**	**0.73**	**0.75**
Departure from 12-year normal				**−0.04**	**−0.02**	**−0.02**	**+0.03**	**−0.06**	**−0.04**	**+0.02**

MADISON, WIS.

Date.	Sun's zenith distance. 0.0°	48.3°	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°
	Air mass. 1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
A. M.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.
Dec. 2				1.38	1.28					
13				1.34						
15						1.22		1.04		
26				1.31						

[1] Extrapolated and reduced to mean solar distance.

TABLE 1.—*Solar radiation intensities during December, 1919*—Contd.

MADISON, WIS.—Continued.

Date.	Sun's zenith distance. 0.0°	48.3°	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°
	Air mass. 1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
A. M.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal
Monthly means				**1.34**	**(1.28)**	**(1.22)**		**(1.04)**		
Departure from 10-year normal				**+0.04**	**+0.07**	**+0.07**		**−0.01**		
P. M.										
Dec. 2				1.36	1.36	1.28				
29						1.05	0.98			
Monthly means				**(1.36)**	**(1.36)**	**(1.16)**	**(0.98)**			
Departure from 10-year normal					**+0.06**	**−0.03**	**−0.12**			

LINCOLN, NEBR.

Date.	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
A. M.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.
Dec. 2				1.27	1.17	1.07				
9				1.40						
15						1.09				
26				1.35	1.28	1.21	1.17			
30				1.26	1.20	1.15	1.09		0.93	
Monthly means				**1.32**	**1.22**	**1.13**	**(1.13)**		**(0.93)**	
Departure from 5-year normal				**+0.02**	**−0.02**	**±0.00**	**+0.08**		**+0.05**	
P. M.										
Dec. 2				1.26	1.18	1.10	1.03	0.97	0.90	
9				1.35	1.30	1.23	1.17	1.10	1.05	0.99
15					1.11	1.03	0.93	0.88	0.84	
16				1.28		1.10	1.06	0.97	0.90	0.83
26				1.34	1.28	1.21	1.13	1.08	1.02	0.97
29				1.30	1.22	1.18	1.14			
30				1.32	1.26	1.21	1.16		1.06	
Monthly means				**1.31**	**1.22**	**1.15**	**1.09**	**1.00**	**0.96**	**0.93**
Departure from 5-year normal				**+0.03**	**+0.02**	**+0.01**	**±0.00**	**−0.03**	**−0.01**	**−0.01**

SANTA FE, N. MEX.

Date.	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
A. M.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.
Dec. 10					1.14					
13			1.56							
20					1.40	1.37				
22			1.45	1.42	1.38					
23			1.57							
26			1.52							
29			1.47	1.47	1.44	1.33	1.23			
31						1.17				
Monthly means			**1.51**	**(1.44)**	**1.34**	**1.29**	**(1.23)**			
Departure from 5-year normal			**+0.01**	**+0.01**	**−0.02**	**−0.01**	**−0.01**			
P. M.										
Dec. 12					1.41	1.33	1.26	1.19	1.13	
13				1.49	1.43	1.37	1.32	1.26	1.21	
23				1.46	1.25					
Monthly means				**(1.48)**	**1.36**	**(1.35)**	**(1.29)**	**(1.22)**	**(1.17)**	
Departure from 5-year normal				**+0.07**	**+0.04**	**+0.08**	**+0.06**	**+0.06**	**+0.08**	

TABLE 2.—*Vapor pressures at pyrheliometric stations on days when solar radiation intensities were measured.*

Washington, D. C.			Madison, Wis.			Lincoln, Nebr.			Santa Fe, N. Mex.		
Date.	8 a.m.	8 p.m.	Date.	8 a.m.	8 p.m.	Date.	8 a.m.	8 p.m.	Date.	8 a.m.	8 p.m.
1919.	*mm.*	*mm.*	1919.	*mm.*	*mm.*	1919.	*mm.*	*mm.*	1919.	*mm.*	*mm.*
Dec. 1	2.62	3.30	Dec. 2	0.64	0.71	Dec. 2	0.96	1.07	Dec. 10	2.49	2.62
3	1.68	2.06	13	0.86	0.46	9	0.64	0.51	12	2.16	2.74
4	1.88	2.74	15	0.41	0.43	15	1.24	1.88	13	2.26	0.71
10	2.49	1.19	16	3.63	3.15	16	1.37	2.87	20	1.78	2.06
11	1.45	2.06	29	3.00	3.45	26	3.63	3.99	22	2.62	2.87
15	1.78	1.78				29	4.17	4.95	23	2.06	2.49
16	1.37	2.62				30	3.81	4.75	26	2.16	1.78
20	1.78	1.68							29	1.96	1.60
21	1.19	2.26							31	1.68	1.68
22	2.49	3.15									
30	2.87	2.49									
31	2.87	4.37									

TABLE 3.—*Daily totals and departures of solar and sky radiation during December, 1919.*

[Gram-calories per square centimeter of horizontal surface.]

Day of month.	Daily totals.			Departures from normal.			Excess or deficiency since first of month.		
	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.
	cal.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
1	249	86	105	77	−46	−86	77	−46	−86
2	141	222	291	−29	91	102	48	45	16
3	266	202	252	98	72	65	146	117	81
4	240	68	215	74	−62	30	220	55	111
5	101	178	106	−63	49	−77	157	104	34
6	32	54	93	−131	−75	−89	26	29	−55
7	188	123	229	26	−6	48	52	23	−7
8	24	208	104	−137	79	−76	−85	102	−83
9	32	132	319	−128	3	140	−213	105	57
10	198	204	280	38	75	102	−175	180	159
11	229	153	213	70	25	36	−105	205	195
12	68	126	188	−90	−2	12	−195	203	207
13	118	213	277	−40	85	102	−235	288	309
14	100	206	264	−57	78	90	−292	366	399
15	232	225	237	76	97	63	−216	463	462
16	247	91	232	91	−37	58	−125	426	520
17	170	109	226	14	−20	52	−111	406	572
18	100	92	198	−56	−37	24	−167	369	596
19	29	174	69	−127	44	−105	−294	413	491
20	218	63	76	62	−68	−98	−232	345	393
Decade departure.							−57	165	234
21	196	59	143	40	−72	−30	−192	273	363
22	216	98	73	59	−34	−100	−133	239	263
23	225	99	211	68	−33	38	−65	206	301
24	54	124	28	−103	−9	−145	−168	197	156
25	228	138	67	71	4	−106	−97	201	50
26	120	178	256	−37	43	82	−134	244	132
27	91	103	75	−67	−33	−100	−201	211	32
28	78	176	196	−80	39	20	−281	250	52
29	160	121	242	1	−17	65	−280	233	117
30	195	174	249	36	35	70	−244	268	187
31	204	143	106	44	3	−74	−200	271	113
Decade departure.							+32	−84	−280
Excess or deficiency since first of year — Gr.-cal.							−7,389	−4,331	−4,435
Excess or deficiency since first of year — Per cent.							−5.9	−3.6	−3.2

MEASUREMENTS OF THE SOLAR CONSTANT OF RADIATION AT CALAMA, CHILE.

By C. G. ABBOT.

[Dated: Astrophysical Observatory, Smithsonian Institution, Washington, Jan. 27, 1920.]

In continuation of preceding publications I give in the following table the results obtained at Calama, Chile, in November, 1919, for the solar constant of radiation. The reader is referred to this REVIEW for February, August, and September, 1919, for statements of the arrangement and meaning of the table.

The intensity of solar radiation during November was generally unusually high.

Date.	Solar constant.	Method.	Grade.	Transmission coefficient at 0.5 micron.	Humidity. ρ/ρ s.c.	Humidity. V. P.	Relative humidity.	Remarks.
1919. A. M.	*cal.*					*cm.*	%	
Nov. 1	1.960	M_3	S−	0.860	0.634	0.18	19	Scattered cirri in east and west.
	1.950	M_2						
	1.966	$M_{1.5}$						
	1.957	W. M						
2	1.957	$M_{1.65}$	S	.864	.797	.11	10	Cirri scattered about whole sky.
3	1.957	$M_{1.16}$	S−	.862	.746	.18	12	Scattered cirri about whole sky.
4	1.960	$M_{1.5}$	S−	.864	.766	.18	12	Scattered cirri about sky.
5	1.956	E_0	VG+	.862	.634	1.6	16	Cirri in west and northeast.
	1.971	M_3						
	1.977	M_2						
	1.966	$M_{1.5}$						
	1.969	W. M						
P. M. 6	1.952	$M_{1.11}$	S−	.850	.764	.26	9	Cirri in east and west.
A. M. 7	1.939	M_3	S	.868	.734	.14	14	Thin cirri in north, east, and southwest.
	1,947	M_2						
	1.944	W. M						
9	1.948	$M_{1.02}$	S−	.864	.756	.45	24	Cirri in north and east.
10	1.950	E_0	E−	.864	.560	.28	28	Some cirri low in east and north.
	1.968	M_3						
	1.950	M_2						
	1.961	$M_{1.5}$						
	1.960	W. M						
11	1.966	$M_{2.15}$	S−	.846	.572	.26	23	Scattered cirri, especially in north and east.
12	1.957	M_3	S	.849	.498	.24	22	
	1.966	M_2						
	1.958	$M_{1.5}$						
	1.961	W. M						
13	1.966	M_2	S	.846	.559	.29	21	Scattered cirro-cumuli in east and north.
	1.954	$M_{1.37}$						
	1.960	W. M						
15	1.921	M_3	S	.848	.456	.29	26	Cirri in west and distant east.
	1.949	M_2						
	1.952	$M_{1.5}$						
	1.947	W. M						
17	1.911	E_0	E−	.862	.526	.23	24	Cirri in east, north, and west, moving south.
	1.921	M_3						
	1.940	M_2						
	1.926	$M_{1.5}$						
	1.925	W. M						
18	1.959	M_3	S	.858	.510	.24	22	Distant cirri in east and northwest.
	1.971	M_2						
	1.958	$M_{1.5}$						
	1.961	W. M						
21	1.952	$M_{1.5}$	S	.850	.591	.34	24	Scattered cirri.
	1.956	$M_{1.69}$						
	1.954	W. M						
22	1.950	$M_{1.5}$	S−	.849	.619	.30	22	Thin cirri in early a.m. gradually disappearing
	1.934	$M_{1.64}$						
	1.940	W. M						
23	1.952	M_2	S+	.846	.552	.28	20	Cirri in east and north, and some in west.
	1.950	$M_{1.5}$						
	1.951	W. M						
24	1.952	M_3	S−	.843	.546	.33	26	Cirri in north and east, moving rapidly south.
P. M. 25	1.944	$M_{1.12}$	S−	.854	.645	.44	17	Scattered cirri over whole sky.
A. M. 26	1.968	$M_{1.5}$	S−	.855	.632	.29	22	Cirri in north and east spreading west and moving south.
27	1.913	E_0	VG	.845	.464	.24	23	Distant cirri in north and east.
	1.949	M_3						
	1.964	M_2						
	1.928	$M_{1.5}$						
	1.936	W. M						
28	1.958	M_2	S	.851	.601	.28	23	
	1.956	$M_{1.5}$						
	1.957	W. M						
29	1.950	M_2	S	.854	.672	.15	14	
	1.953	$M_{1.5}$						
	1.952	W. M						
30	1.955	M_2	S	.856	.638	.21	18	Some cirri in north and east.
	1.956	$M_{1.48}$						
	1.956	W. M						

WEATHER OF THE MONTH.

WEATHER OF NORTH AMERICA AND ADJACENT OCEANS.

GENERAL CONDITIONS.

By A. J. HENRY, Meteorologist.

The month as a whole was characterized by unusual climatic extremes—severe cold in localities and high temperature in others. Flood-producing rains fell in the East Gulf States, while there was a marked deficiency in adjoining regions. Two rainstorms which overlapped were responsible for one of the greatest floods in the rivers of Alabama and Georgia within the last 25 years.

Very stormy conditions prevailed over the North Atlantic, although the storms of the continental area to the westward were not unusually severe.

NORTH PACIFIC OCEAN.

By F. G. TINGLEY, Meteorologist.

December appears to have been a quiet month on the North Pacific Ocean. Only one vessel of some 75 which have thus far reported made special mention of stormy weather. Winds of gale force were experienced on a total of 43 days of the 533 covered by reports of ships on trans-Pacific routes.

The American S. S. *Saint Francis*, Capt. N. Y. Okland, from Honolulu for Yokohama, reports that on December 1, while in latitude 21° 25′ N., longitude 160° 20′ E., three waterspouts were observed; also, on the same day, a lunar rainbow.

NORTH ATLANTIC OCEAN.

By F. A. YOUNG.

The average pressure for the month was nearly normal or slightly above at land stations on the American coast, including the Gulf of Mexico, and also the Bermudas. The pressure at the Azores was considerably higher than usual, while it was well below the normal on the coast of northern Europe, causing an abnormally steep gradient between the Azores HIGH and the Icelandic LOW, that was responsible for the unusually heavy winds that prevailed over the region intervening. In a number of 5-degree squares near mid-ocean, winds of gale force were observed on 11 days, which is considerably above the normal as shown on the Pilot Chart for December. There was practically not a day in the month on which heavy weather was not experienced in some portion of the ocean.

The disturbance that was shown on Charts XIII and XIV for November 29 and 30, respectively, drifted slowly eastward and on December 1 the center was near latitude 56°, longitude 17° (see Chart IX); it had decreased considerably in intensity, as only moderate winds were reported. On the same day there was a second LOW of much greater force, central a short distance east of St. Johns, Newfoundland. The storm area extended from the 30th meridian to the coast of Newfoundland, and a number of vessels encountered southwesterly gales of from 50 to 60 miles an hour, accompanied by rain or hail. This disturbance moved eastward with a fairly uniform rate of movement, attended by little change in conditions of wind and weather, and on the 3d was off the coast of northern Europe (see Charts X and XI). On the 4th and 5th, moderate to strong gales, with comparatively high barometer readings prevailed over a limited territory covering the eastern part of the steamer lanes, and on the 6th and 7th heavy northerly winds were encountered off the British coast. From the 10th to the 13th, as shown on Charts XII, XIII, XIV, and XV, heavy gales swept the greater portion of the northern division of the ocean, accompanied by rain, hail, and snow. The observer on the Norwegian S. S. *Ranenfjord* states in the storm log that the gale began on the 9th. Lowest barometer, 28.56 inches at 11 a. m. on the 12th, winds WSW., force 11; position 52° 20′ N., 45° 45′ W. End of gale on the 14th, highest force 11. Shifts of wind near time of lowest barometer SE.-S.-SW.-W.-WNW.

The log from the British S. S. *Suwanee* is as follows: "Gale began on the 11th. Lowest barometer, 29.16 inches at 8 a. m. on the 11th; position, 49° 55′ N., 44° 50′ W. End of gale on the 13th; highest force, 10; shifts of wind WSW.-SW."

From the 14th to the 20th reports were received from widely scattered positions over the ocean denoting winds of gale force, although there was not enough data from northern waters to determine the conditions accurately. On the morning of the 14th the station at New York reported a southwest gale of about 50 miles an hour, while at the same time a vessel near latitude 36°, longitude 69°, encountered southerly winds of the same force.

On the 17th the British S. S. *Tullamore*, while about 300 miles north of Bermuda, encountered a southwesterly gale, the storm log being as follows: "Gale began on the 16th. Lowest barometer, 29.52 inches at 4 p. m. on the 17th; position, 36° 32′ N., 63° 52′ W. End of gale on the 18th. Highest force of wind, 11. Shifts WSW.-NW." The British S. S. *Hotham Newton*, on her voyage from the British Isles to New York, extending from December 21 to January 10, ran into a succession of gales, and on only two days from the time she left Swansea until January 6 were wind velocities of less than 40 miles an hour recorded at time of observation. Her storm log is as follows: "Gale began on December 20. Lowest barometer, 29.14 inches on the 28th; position, 47° 50′ N., 26° 30′ W. End of gale on the 30th. Highest force of wind, 11; shifts WSW.-NW." During the 21st and 22d this gale swept the British Isles, although the storm area extended well into mid-ocean. The storm log of the British S. S. *Ernmore* is as follows: "Storm began on the 22d. Lowest barometer, 29.40 inches at noon on the 23d; position, 53° 56′ N., 51° 57′ W. End of gale on the 24th. Highest force of wind, 10; shifts WSW.-W."

From the 23d to the 27th strong westerly and southwesterly gales, accompanied by hail, prevailed over the region between the 30th meridian and the European coast, although reports were received from several vessels in this area that experienced only moderate winds.

From the 28th to the 30th moderate gales were prevalent over the southern steamer routes between the 20th and 40th meridians, extending on the latter date as far south as the Azores. On the 31st the disturbance had increased considerably in intensity, while its easterly drift had been slight since the 28th, as it was now central near latitude 51°, longitude 25°. A number of vessels

in the westerly quadrants encountered northerly gales of from 50 to 75 miles an hour, as shown by the storm log of the British S. S. *Stanmore*, which is as follows: "Gale began on the 31st. Lowest barometer, 28.84 inches at 7 a. m. on the 31st; position, 49° 54′ N., 30° 07′ W. End of gale 4 p. m. on the 31st. Highest force of wind, 11. Shifts of wind near time of lowest barometer reading, SE.-NW." On the 31st strong northwest gales, accompanied by snow, were also reported from a limited area immediately south of Halifax, Nova Scotia. The storm log of the British S. S. *Cretic* is as follows: "Gale began on the 31st. Lowest barometer, 28.88 inches at 4 a. m. on the 31st; position, 41° 57′ N., 61° 25′ W. End of gale on the 31st. Highest force of wind, 11; shifts, SE.-NW."

Fog was comparatively rare during the month, as it was reported on only three days on the Banks of Newfoundland and in the waters adjacent to the American coast north of the 40th parallel, while over the middle and eastern section of the steamer lanes it was even less frequent.

NOTES ON WEATHER IN OTHER PARTS OF THE WORLD.

British Isles.—"An abnormally cold November gave place to a period in which mild winds from some westerly quarter * * * were largely in evidence. As regards temperature the contrast between the two months was therefore very striking.

"The general rainfall expressed as a percentage of the average was as follows: England and Wales, 155; Scotland, 130; Ireland, 156.

"In London (Camden Square) the month was unusually showery and mild. Rain fell on all but 5 days, and a rain spell lasted from the 13th to the 31st. Mean temperature, 42.7° or 3° above the average [and 3° F. higher than November]."[1]—*Symons's Meteorological Magazine, Jan., 1920.*

France.—Paris, December 23.—Unseasonably warm weather has prevailed throughout France recently, but severe windstorms have caused a number of wrecks in the English Channel, the Mediterranean, and the Atlantic. Great damage has been done in northern France, houses being demolished in the Lille district.—*N. Y. Evening Post.*

Troyes, December 26.—The Seine and the Aube are rising rapidly. The inhabitants of the Mathaux quarter have been obliged to evacuate their dwellings.—*N. Y. Tribune.*

Nancy, December 26.—The floods are subsiding as rapidly as they rose. The damage done by the waters is estimated at more than $2,000,000. Most of the metal and other industrial plants ceased operations. Railroad communication is partly interrupted, large portions of the track north of the city having been washed away.—*N. Y. Tribune.*

[1] See note in Nature (London), Jan. 8, 1920, p. 475, which discusses the special meteorological features of the year.

Colmar, December 26.—The plain between the Rhine and the railroad from Mulhausen to Schlestadt is one vast sheet of water. The inhabitants of many villages in the valley have been driven from their homes. At St. Croix, a number of houses have been swept away and several persons injured.—*N. Y. Tribune.*

Switzerland.—Geneva, December 26.—Melting snow from the lower Alps has swollen the Rhine River to 12 feet above normal. Tramway service in Basel has been reduced one-half.

Heavy snows are continuing in eastern Switzerland, a fresh fall of 20 inches being reported from Davos and St. Moritz. Many trains are stalled.—*N. Y. Tribune.*

Germany.—Berlin, December 27.—Lowlands near Mannheim, where the Neckar River flows into the Rhine, and for many miles above and below that point, are inundated by the Rhine flood, the overflowing being the worst experienced since the record flood of 1896. Heavy snows which fell in November are melting under warm rains falling over the Black Mountains and have swelled all rivers in southern Germany, many railroad stations being under water.

Dams near Freiburg, controlling water for a number of cities, have broken and railroad transportation is stopped in many sections.

Paris, December 28.—Floods along the Rhine and streams flowing into it are higher than they have been for 38 years and great damage is being done by the inundation, according to a Mainz dispatch.—*N. Y. World.*

China.—Amoy, September 8.—A great typhoon swept over the southeast coast last Monday, resulting in the death of at least 3,000 persons, according to reports from Fu-Chow. The typhoon was accompanied by a tidal wave 28 feet high.—*N. Y. Globe, Sept. 8, 1919.*

DETAILS OF THE WEATHER OF THE MONTH IN THE UNITED STATES.

CYCLONES AND ANTICYCLONES.

By A. J. HENRY.

Cyclones.—Practically all of the cyclones of the month first appeared in the daily Weather Maps off the coast of British Columbia and either moved thence eastward along the northern circuit or secondaries were developed over the plateau region and later crossed the mountains and advanced eastward in the form of NE.-SW. troughs of low pressure. High pressure, which prevailed over the Great Basin from the 13th until the close of the month, seemed to retard and, in some cases, to prevent the eastward movement of cyclones that appeared off the Washington coast. From the 1st to the 13th, secondary cyclones passed across the mountains south of Wyoming. After the 13th the movement was more directly eastward along the northern circuit. None of the cyclones was of pronounced type except that one which moved in from the Pacific on the 10th at a time when the surface was snow-covered, although surface temperature west of the divide on this date was above freezing; east of the divide the temperature was considerably below zero and there was a strong temperature-pressure gradient extending SE.-NW. across Wyoming, southwestern Montana, and eastern Idaho. The Weather Maps of the 11th and 12th are typical of the surface conditions under which a well-developed cyclone crosses the Rocky Mountains in the winter season. The motion from the Pacific is southeastward until the Great Plains of Colorado and Kansas are reached, thence northeast to the Lake region. It is worthy of note that the deep cyclone over southern Idaho on the 11th was immediately followed by a strong anticyclone which persisted in that region until the close of the month, as mentioned in the next paragraph.

Anticyclones.—The weather was distinctly under anticyclonic control the greater part of the month. A strong anticyclone moved from the northern Rocky Mountain region on the 1st to the middle Atlantic coast by the 4th. This was followed by two others, with a cyclone intervening between each of them. The pronounced cyclone of the 10th was followed by a strong anticyclone which had become firmly established over southern Idaho on the morning of the 13th. It remained practically stationary with undiminished intensity during the 14th-16th. Then pressure fell somewhat in its northwestern quadrant, thus automatically shifting the center of highest pressure to western Colorado, where it remained from the 20th to 25th. On the 26th, pressure having risen over Idaho and Nevada, the center was again established over southern Idaho, where it remained until about the close of the month. The winter-pressure distribution thus described, so long as it continues, seems to have an important bearing upon the weather of the United States as a whole. Some of the associated conditions are as follows: Generally dry weather with frost in California away from the coast; Chinook winds east of the mountains in Idaho and western Montana; frequent alternations of high and low temperature east of the Mississippi and north of the Ohio but no severe cold.

THE WEATHER ELEMENTS.

By P. C. DAY, Climatologist and Chief of Division.

[Dated: Weather Bureau, Washington, Feb. 2, 1920.]

PRESSURE AND WINDS.

At the beginning of the month high pressure was advancing from the British northwest, and severe cold for the season had overspread most northern and central districts. The high area extended into the more eastern districts, and by the middle of the first decade had passed off the middle Atlantic coast. In the meantime there was a general reduction in pressure over northern and far western districts, but elsewhere the pressure still continued above normal.

During the latter half of the first decade pressure diminished over the South, and storm areas, forming over the Southwest, moved easterly, causing rain or snow over large areas. Toward the close of the decade, however, high pressure again moved into the Northwest and by the close it had advanced into the middle Mississippi Valley, where the sea-level values were nearly 31 inches, the highest ever observed in December at several points. In much of the West the coldest weather of the month was observed, about this time, the minimum temperatures over the Great Plains and Rocky Mountain regions on the morning of the 9th ranging from 30° to nearly 50° below zero (F.).

While this high area was advancing toward the Atlantic coast, there was a sharp reaction to lower pressure in the far West, which likewise moved eastward reaching the Atlantic coast about the middle of the second decade. In the far West, however, there was a quick return to above normal pressure and by the morning of the 14th sea-level pressure was near 31 inches in the northern plateau, the reading at Boise, Idaho, 30.96 inches, being the highest ever observed at that place. In connection with this high pressure, severe cold prevailed in the far Northwest, the minimum temperature falling to 50° or more below zero (F.) at exposed points in Idaho and Montana. The lowest temperatures ever observed in December occurred during this period at numerous places, and at some points they were the lowest observed in any winter month. High pressure and severe cold continued throughout most central and western districts until after the middle of the second decade; and in portions of the plateau, pressure remained high and severe cold continued until the end.

During the third decade of the month, lower pressure was the rule in practically all parts of the country, although a high area of moderate intensity was maintained over the plateau region during the greater part of the decade, assuming considerable proportions at times, but confined in the main to districts west of the Rocky Mountains, until the end of the month when it shifted to the Missouri Valley and colder weather had again overspread the Northwest. In the central and southern portions of the country pressure was generally falling at the close of the month, with the lowest barometer readings over the middle Mississippi Valley.

The average pressure for the month (Chart VII and Tables I and III) was above normal over the entire country, and in Canada as well, as far as available observations disclose. In portions of the Rocky Mountains and plateau region the pressure averaged decidedly higher than normal and this persisted to some extent over the Canadian northwest and generally over the central and northern portions of the interior valleys. The excess was least over the South Atlantic and East Gulf States and along the central and south Pacific coast, where the averages were usually only slightly above normal.

The winds were usually moderate in character, and high velocities were confined mostly to coast disctricts, particularly at exposed points along the middle and north Pacific coast sections, where high winds are usual at this period of the year, and along the Atlantic coast from New York to Nantucket, where about the 10th and 11th and again on the 15th some high winds occurred. Over much of the country to eastward of the Rocky Mountains the winds were mainly between northerly and westerly points, although in portions of the Lake region and Ohio Valley there was a strong tendency toward southwest winds. In the far Northwest there was a considerable tendency to easterly winds due to diminishing pressure toward the Pacific coast.

TEMPERATURE.

December, 1919, was a month of almost continued cold over the greater part of the country, but particularly so in the central and northern mountain and plateau districts, where in some cases the temperature was below normal nearly the entire month. At Grand Junction, in western Colorado, the daily means were continuously below normal, usually to a large degree, except on three dates when there were slight excesses, the average for the month being the lowest ever reported in December, at that place. At Walla Walla, in southeastern Washington, the mean daily temperatures were continuously below normal during the first two decades of the month. The departures from the normal for the 15-day period, December 2–16, inclusive, averaging more than 30° (F.) per day, and during the 5-day period, from the 11th to 15th inclusive, the average departure was −40° (F.) per day. Severe cold set in over that district about November 25 and, continuing without material interruption until the end of the second decade in December, comprised a period of the most severe and long-continued cold in the known history of that section.

The period from about the 8th to 13th was probably one of the longest with continued severe cold ever experienced in the far Northwest. At Rapid City, in western South Dakota, the temperature was continuously below zero for more than five days, and on the extreme northern coast of Washington, despite the surrounding ocean warmth, the temperature at Tatoosh Island, remained below freezing for the same period, a record not previously observed at that place.

Farther east, over the Northern Plateau States, there was a considerable moderation in temperature during the latter half of the month, but here severe cold had been almost continuous since the early part of October, and while the current month as a whole was not so cold as in some previous years, the period October 9 to December 16 was on the whole one of the coldest ever known. At Williston, N. Dak., the daily temperatures during that period, 69 days, averaged more than 14° F. per day below normal.

In general the coldest period of the month was from the 9th to 15th, when minimum temperatures ranged from 24° F. above zero in northern Florida to 52° F. below zero in Montana. In portions of the Ohio Valley, and from Virginia northward to New England, the coldest period was about the close of the second decade.

The highest temperatures for the month were generally observed near the end, although over the Southern States, from Texas eastward, the warmest period was during the latter part of the first decade. Along the South Atlantic coast and in portions of Florida the maximum temperatures on the 8th and 9th were at numerous points the highest ever observed in December. At the same time the lowest temperatures ever observed were being experienced in the Rocky Mountain region. At points in southern California the maximum temperatures on the 28th were in excess of any previously experienced in that section in December.

For the month as a whole, the temperature averaged below normal in nearly all portions of the country. In a few cases, particularly in the northern districts from the Mississippi Valley eastward, the month was as a whole colder than December, 1917. At a few points in the far Northwest it was likewise the coldest December of record. Over the Southern States to eastward of Texas the month, as a whole, was slightly warmer than the average, and there was a small area in the far Southwest with similar conditions.

PRECIPITATION.

The month was notably free from well-developed storms and attendant wide areas of precipitation usual to a winter month.

The principal storm periods of the month occurred during the latter half of the first decade. The first moved from the southern Plains region to New England during the 6th and 7th, accompanied by very general though moderately light precipitation over most districts from the Great Plains eastward. The second and principal storm of the month moved rapidly from the far Southwest during the 8th, and by the morning of the 9th was central in the Ohio Valley from whence it moved during the following 24 hours to the lower St. Lawrence Valley. This storm brought more or less precipitation to nearly all parts of the country, snow over the northern and rain in the central and southern districts. In portions of the Middle Gulf States the precipitation was markedly heavy, particularly in eastern Mississippi, the greater part of Alabama, and over much of western Georgia. In some cases the falls from the 7th to the 9th ranged from 10 to 12 inches, the 24-hour amounts frequently ranging from 5 to 7 inches or more. These heavy rains caused some of the worst floods ever known in the regions referred to, with heavy property damage and some loss of life. Considerable precipitation occurred over the more eastern districts during the 13th and 14th, but from that period until the end of the month only light local precipitation occurred in any part of the country, in fact the last half of the month was remarkably free from stormy weather of any sort for a winter month.

For the month as a whole precipitation was below normal in nearly all parts of the country, and in portions of the South Atlantic States the drought that has persisted for several months still remained unbroken at the end of the year. At Savannah, Ga., and Charleston, S. C., the amounts for the month, with one exception, were the least for December in nearly 50 years. Over a small area in the Middle Gulf States, notably in Alabama and the adjoining portions of Mississippi and Georgia, the heavy

precipitation during the latter part of the first decade exceeded largely the normal for the entire month, and small excesses occurred in portions of South Carolina, Kentucky, and West Virginia, and similar conditions prevailed in portions of Wyoming and Montana.

SNOWFALL.

For a winter month December, 1919, had, as a rule, much less snow than usually falls. A few limited areas had unusually large amounts for single storms but, for the month as a whole, the total depths were nearly everywhere unusually small.

At local points in the Middle Plateau, the snowfall during the first few days of the month was unusually heavy for that region and, due to continued cold, remained on the ground for a considerable period. Likewise on the 9th and 10th a heavy fall of snow occurred over nearly all portions of the far Northwest. In portions of Oregon, Washington, and Idaho, the depths at the lower elevations were the greatest ever reported for a single storm; and on account of the severe cold existing at the time, it remained on the ground for a much longer period than usual. In the upper Michigan Peninsula the snowfall, though usually light for individual falls, nevertheless amounted in places to over 4 feet for the entire month.

At the end of November a larger part of the country than usual was snow-covered, the depths being particularly large for so early in the winter over the northern districts from the Great Lakes westward and generally in the mountain regions of the West. On account of the frozen condition of this snow, owing to severe cold, it remained on the ground unmelted for long periods, particularly in the Northern Plains, and mountain districts and much suffering to stock resulted from inability to secure the food usually available on the ranges and the frequent lack of any provisions for feeding in other ways so early in the winter.

RELATIVE HUMIDITY.

Wide variations in the relative humidity values for near-by stations are shown when compared with the normal, some of which are doubtless due to the difficulty experienced in securing accurate data at low temperatures. As a whole, however, the relative humidity was above the normal for December over the greater part of the country, marked exceptions occurring, however, over the southeastern and far northwestern districts, where the values were in some cases decidedly below normal.

SEVERE STORMS.

The occurrence of a tornado was reported at Marion, Miss., at 3:18 p. m., December 7. Considerable property damage was sustained and one person was killed.

Winds of 50 mi./hr. (22.4 m./sec.) or more during December, 1919.

Stations.	Date.	Velocity.	Direction.	Stations.	Date.	Velocity.	Direction.
Block Island, R. I.	10	60	nw.	North Head, Wash.	19	62	s.
Do.	15	58	nw.	Do.	20	64	s.
Buffalo, N. Y.	10	54	w.	Do.	22	70	s.
Do.	13	54	sw.	Do.	23	58	se.
Do.	15	57	w.	Do.	24	62	s.
Do.	26	58	sw.	Pittsburgh, Pa.	30	53	nw.
Burlington, Vt.	10	52	nw.	Pocatello, Idaho	11	50	s.
Do.	12	52	s.	Do.	12	52	sw.
Cheyenne, Wyo.	9	52	w.	Point Reyes Light, Calif.	4	85	s.
Do.	10	54	w.	Do.	5	59	se.
Do.	14	60	w.	Do.	7	58	nw.
Do.	15	50	w.	Do.	8	65	nw.
Duluth, Minn.	29	51	nw.	Do.	9	56	s.
Ellendale, N. Dak.	25	50	nw.	Do.	10	63	s.
Erie, Pa.	11	50	se.	Do.	11	54	sw.
Lander, Wyo.	10	56	sw.	Providence, R. I.	10	66	nw.
Mount Tamalpais, Calif.	4	66	se.	St. Louis, Mo.	12	51	sw.
Do.	5	52	se.	Sandy Hook, N. J.	10	52	nw.
Do.	7	60	nw.	Tatoosh Island, Wash.	1	56	ne.
Do.	8	58	nw.	Do.	2	51	e.
Do.	9	50	se.	Do.	9	70	ne.
Do.	10	58	s.	Do.	10	62	ne.
Do.	11	52	sw.	Do.	18	59	s.
Nantucket, Mass.	25	52	ne.	Do.	19	52	e.
New York, N. Y.	10	72	nw.	Do.	20	62	s.
Do.	15	50	w.	Do.	22	59	s.
Do.	17	52	nw.	Do.	23	55	s.
North Head, Wash.	16	68	s.	Do.	26	54	s.
Do.	17	62	se.				

Average accumulated departures for December, 1919.

Districts.	Temperature.			Precipitation.			Cloudiness.		Relative humidity.	
	General mean for the current month.	Departure for the current month.	Accumulated departure since Jan. 1.	General mean for the current month	Departure for the current month.	Accumulated departure since Jan. 1.	General mean for the current month.	Departure from the normal.	General mean for the current month.	Departure from the normal.
	°F.	°F.	°F.	In.	In.	In.	0-10		P. ct.	
New England	24.6	− 4.5	+12.5	2.18	−1.20	+ 1.11	6.5	+0.3	76	0
Middle Atlantic	31.6	− 3.7	+22.7	2.43	−0.80	− 3.70	6.6	+0.8	74	−1
South Atlantic	47.0	− 0.2	+21.7	1.86	−1.60	− 9.50	5.2	+0.3	75	−2
Florida Peninsula	67.9	+ 1.5	+ 5.0	1.45	−0.60	+ 3.60	4.2	−0.4	77	−5
East Gulf	50.2	+ 1.1	+16.1	6.95	+2.40	+11.86	5.3	−0.2	76	−1
West Gulf	47.8	− 1.2	− 3.2	1.35	−1.50	+ 8.95	6.3	+1.1	72	−2
Ohio Valley and Tennessee	32.3	− 4.3	+16.1	3.46	00	+ 3.40	6.5	+0.1	77	0
Lower Lakes	23.2	− 6.0	+16.4	1.44	−1.40	− 1.10	7.3	−0.5	75	−4
Upper Lakes	16.2	− 8.3	+21.5	1.31	−0.80	− 2.20	7.5	+0.2	82	0
North Dakota	8.4	− 3.4	+ 8.3	0.42	−0.20	− 2.35	5.0	−0.6	86	+5
Upper Mississippi Valley	19.1	− 8.1	+13.6	0.72	−1.10	+ 2.00	6.9	+0.9	82	+3
Missouri Valley	22.2	− 4.6	+13.6	0.34	−0.70	− 2.20	5.5	+0.2	83	+7
Northern slope	18.4	− 5.2	+ 5.9	0.78	−0.10	− 1.80	4.6	−0.7	74	+1
Middle slope	30.0	− 3.2	+ 2.6	0.27	−0.50	− 3.83	3.8	−0.4	74	+6
Southern slope	42.4	− 1.3	−12.3	0.32	−0.50	+ 0.10	4.7	+0.2	66	−2
Southern Plateau	40.9	+ 1.6	+ 6.8	0.31	−0.40	+ 1.19	2.9	−0.3	57	+6
Middle Plateau	25.0	− 6.3	− 1.9	1.13	+0.20	− 2.20	4.3	−0.8	75	+3
Northern Plateau	21.8	−10.2	− 2.3	1.54	−0.20	− 2.30	6.9	00	82	+2
North Pacific	38.5	− 3.6	+ 3.1	5.32	−2.40	− 9.60	6.7	−1.1	81	−6
Middle Pacific	46.6	− 2.0	− 9.2	3.24	−1.20	− 6.30	5.9	+0.4	78	−1
South Pacific	53.9	+ 1.0	+ 5.1	1.97	−0.20	− 4.90	3.8	−0.5	67	−1

SPECIAL FORECASTS AND WARNINGS. WEATHER AND CROPS.

WEATHER WARNINGS, DECEMBER, 1919.

By EDWARD H. BOWIE, Supervising Forecaster.

[Dated: Weather Bureau, Washington, Jan. 17, 1920.]

On the 1st, when an extensive area of high barometer with very low temperature covered the Northwestern States, cold-wave warnings were ordered for Indiana, Kentucky, Tennessee, Mississippi, and Alabama, and on the 2d the display of warnings was extended to the upper Ohio Valley and the Atlantic States north of the Carolinas. On the afternoon of the 2d, the following bulletin was issued to the press:

> Intense cold for the season is now general over the upper Mississippi Valley, the Great Plains States, and the Rocky Mountain Region, and this area of low temperature is advancing eastward and southward. Cold weather will prevail generally east of the Mississippi River within the next 48 hours, and it will be of several days' duration.

The cold wave occurred as forecast over the northern and middle States east of the Mississippi, but did not spread southward beyond Tennessee and North Carolina. The coldest weather of the season, thus far, followed over considerable areas of the region east of the Mississippi. On the afternoon of the 4th small-craft warnings were ordered for Lakes Michigan and Huron, and the evening of the same day southwest storm warnings were displayed on Lakes Erie and Huron. At this time a low of considerable intensity was central north of Lake Huron and moving rapidly eastward. At 8 p. m. of the 5th the weather map showed a low over New Mexico and rapidly falling pressure over the middle Plains States and the Mississippi Valley and on these facts forecasts of snows were issued for the region of the Great Lakes and the North Atlantic States and snows and rains for the Ohio Valley and the Middle Atlantic States. This disturbance advanced rapidly east-northeastward, and the morning of the 6th its center was over southwestern Missouri, with snow and rain in the Ohio Valley and snow in the region of the Great Lakes and over the upper Mississippi and Missouri Valleys. On the morning of the 6th advisory warnings of fresh shifting winds and snow were sent to open ports on Lake Michigan, and on the evening of the same day storm warnings were ordered for the Atlantic coast at and north of Cape Hatteras, when the disturbance was over the Ohio Valley and manifesting a rapid gain in intensity. At 8 a. m. of the 7th the center of this disturbance was over New York and by the 8th the disturbance had passed eastward beyond the coast. The appearance of rapidly rising pressure and falling temperature on the morning of the 7th over the Northwestern States presaged the rapid southward and eastward extension of a cold wave from that region, and at that time cold-wave warnings were ordered for upper Michigan and the evning of the same day for lower Michigan. By the morning of the 8th the cold wave was rapidly spreading southward beyond the Mississippi River with intense cold prevailing in the Northwestern States. On the afternoon of the 8th, cold-wave warnings announcing a severe cold wave for the night of the 9th and the following day were ordered for the East Gulf States, Tennessee, Kentucky, and Indiana, and the morning of the 9th the display of cold-wave warnings was extended to cover lower Michigan, Ohio, western New York, western Pennsylvania, West Virginia, extreme western Virginia, and northern and western Georgia. Also northwest storm warnings were displayed the morning of the 9th on the Gulf coast at and between Cedar Keys, Fla., and Bay St. Louis, Miss., and southeast storm warnings were ordered on the New England coast. Later on the same day northwest storm warnings were displayed on the Atlantic coast at and between New York and Jacksonville, and cold-wave warnings were displayed over the Atlantic States, except southern Florida. Strong winds and gales occurred along the coast where storm warnings were displayed, and the weather was decidedly colder, temperature falling 30 to 40 degrees during the 10th and the night of the 10th generally east of the Mississippi, although the cold-wave warnings failed of verification on the south Atlantic and east Gulf coasts.

On the 10th and 11th the pressure fell decidedly over the western Plateau and increased over the Northwestern States. The western low moved eastward during the 12th, and the pressure continued to increase and the weather became much colder over the Northwestern States. On the 12th cold-wave warnings were ordered for the region of the Great Lakes, the Ohio Valley, Tennessee, and the interior of the East Gulf States, and southwest storm warnings were displayed on the Atlantic coast at and north of Delaware Breakwater. On the 13th cold-wave warnings were repeated for the regions previously warned and extended to the Atlantic States south of Pennsylvania, except the Florida Peninsula. Storm warnings were continued on the north Atlantic coast and ordered for the Gulf coast between Bay St. Louis, Miss., and Cedar Keys, Fla. On the 14th cold-wave warnings were ordered for the Atlantic States north of Maryland and for the northern and central portions of the Florida Peninsula, and northwest storm warnings were ordered at 9.30 a. m. for the Atlantic coast at and between Boston, Mass., and Jacksonville, Fla. On the 15th northwest storm warnings were again displayed over the limited area of the coast between Sandy Hook, N. J., and Provincetown, Mass. The cold wave and storm warnings set forth above were generally fully verified, storm winds occurring as forecast and cold weather prevailing over the entire region east of the Mississippi River, except in extreme southern Florida. On the 23d cold-wave warnings were ordered for northern Michigan, and on the morning of the 24th storm warnings were displayed on the Atlantic coast north of Cape Hatteras in connection with a disturbance that had passed eastward along the northern border to New York followed by steep gradients and northerly winds. At 8 p. m. of the 24th the center of this disturbance was off the southern New England coast, and the night of the 24th north and northwest gales set in over the region where warnings were displayed. On the morning of the 26th when a disturbance of considerable intensity was over the Great Lakes, southwest storm warnings were displayed on the Atlantic coast at and north of Sandy Hook, N. J. On the morning of the 28th cold-wave warnings were ordered for northern Vermont and on the evening of the 29th storm warnings were displayed on the Atlantic coast at and north of Delaware Breakwater, at that time there being a disturbance of considerable intensity over the Great Lakes. On the morning of the 30th, when this disturbance was central over western New York, northwest storm warnings were displayed at coast stations between Cape Hatteras and Delaware Breakwater, and later in

the day the southwest storm warnings at and north of Delaware Breakwater were changed to northwest storm warnings. This storm passed eastward off the New England coast the night of the 30th, attended by strong shifting winds and gales. Cold-wave warnings were ordered on the 31st for parts of upper Michigan, and the afternoon of the same day an advisory message containing information of the eastward movement of a disturbance which was then over the Ohio Valley was sent to ports on the Atlantic coast at and north of Cape Hatteras.

Frequent warnings of strong winds and squalls were sent during the month to open ports on Lake Michigan; also warnings of frosts were sent on a number of occasions during the month to the truck and fruit regions of the East Gulf and South Atlantic States.

WARNINGS FROM OTHER DISTRICTS.

Chicago Forecast District.—The month opened with unusually cold weather prevailing in practically all portions of this forecast district, with the exception of Illinois and Missouri.

On the morning of the 5th advices were telegraphed to Wyoming, north and west South Dakota, and west Nebraska, containing warnings of conditions dangerous to stock interests. During the following 36 hours, while snow fell over a portion of these States and fresh winds occurred, no unusual cold ensued.

On the morning of December 8, unusually cold weather with high pressure prevailed in the northern tier of States, and a marked low was centered over the southern plateau region. These conditions made necessary the issuing of live-stock warnings for the States of Nebraska and Kansas and southeastern Wyoming; and with the southeastward movement of the disturbance in question, these warnings were fully justified.

Live-stock warnings were again issued on December 11 for Wyoming, South Dakota, and Nebraska, and cold-wave warnings for Wyoming and portions of Nebraska, South Dakota, and Iowa, and on the morning of the 12th the warnings were extended to include the eastern and southern portions of the district, and repeated for eastern Wisconsin and eastern and southern Illinois that evening, these warnings being fully verified.

Upon advice received from the central office on the afternoon of December 23, cold-wave warnings were issued for Minnesota, Wisconsin, eastern North Dakota, and northeastern Iowa, but the warning failed of verification because of the high passing rapidly eastward with its center far to the north.

On the morning of the 30th, after a prolonged period of temperature above normal in nearly all sections of the district, a cold high area appeared in the Canadian northwest. Warnings were issued well in advance of this cold weather as it spread rapidly eastward and southward, reaching the southeastern limits of the district on the morning of January 1. A decided drop in temperature occurred in the eastern and southern portions of this district, although in some sections the verifying limit for cold waves was not reached.

Upon the request of the official in charge at Sheridan, Wyo., a special forecast was telegraphed to him on December 22, 1919, as follows:

> From pressure conditions existing Alaska this morning indications point to a continuation of moderate temperature and fair weather north Wyoming next three days. No severe cold now imminent. Conditions latter part of week doubtful.

This forecast was made in the interests of stockmen in the northern portion of Wyoming, who had planned on a large movement of cattle if assured of a continuation of moderate temperature. Ensuing conditions fully justified this advice; in fact, moderate temperatures continued in that section until the close of the month.

Beginning with Tuesday, December 2, and continuing weekly on that day throughout the month, a special forecast was telegraphed to the Weekly Star, Kansas City, Mo., containing the probable weather conditions for the next three days for Kansas, Missouri, southern Iowa, and southern Nebraska, and, when advisable, for the balance of the week. Generally speaking, these forecasts have been most successful.—*E. H. Haines.*

New Orleans Forecast District.—During the first two weeks, storms and cold waves were more frequent than is usual at this time of year; but thereafter the conditions were largely influenced by high pressure over the Great Basin, with comparatively uneventful weather.

Northeast storm warnings were ordered for the east coast of Texas from Port Arthur to Velasco on the morning of the 2d, at which time an area of high pressure was central over the Missouri Valley, with a moderately strong barometric gradient southward. Fresh north winds occurred during the afternoon and night of the 2d.

Another area of high pressure was over the Missouri Valley and northern Rocky Mountain States on the 9th, but with conditions southward more intense than on the 2d. A trough of moderately low pressure was over the West Gulf coast extending northeastward to the Ohio Valley. Northwest storm warnings were ordered at 8.15 a. m. from Port Arthur to Rockport, Tex., and small-craft warnings elsewhere on the west Gulf coast. The small-craft warnings were changed at noon to northwest storm warnings. The warnings were generally verified.

The next "norther" on the Gulf coast occurred on the 13th–14th, for which also timely warnings were issued, northwest storm warnings being ordered on the Texas coast at night on the 12th and on the Louisiana coast the following morning.

No storm occurred without warning.

Cold-wave warnings were issued on the morning of the 1st for Oklahoma and the northern portion of west Texas and were verified the following morning. The warnings were extended in the early afternoon of the 1st over Arkansas and the northern portion of east Texas and at night over the remainder of the district except southern Louisiana, for which cold-wave warnings were issued on the morning of the 2d. A large fall in temperature occurred, with freezing in Arkansas and to the central portion of east Texas; but as the movement of the area of high pressure was eastward, with attendant cloudiness, low temperatures did not reach the verifying limit in the eastern and extreme southern portions of the area for which the cold wave was forecast.

Cold-wave warnings were issued for the Texas Panhandle on the morning of the 8th, and as conditions were critical, 1 p. m. special observations were called for, and warning of a severe cold wave was issued in the early afternoon for the entire district except southern Louisiana, warning for the latter being issued the following morning. The warnings were verified. Zero temperatures and lower were recorded in the extreme northwestern portion of the district, temperature of 3° to 20° in Arkansas, mostly below 25° in the interior of east

Texas and Louisiana, and below freezing to the coast except in extreme southeastern Louisiana.

The night reports of the 11th showed an intense disturbance central over northern Utah and a high over western Canada. Cold-wave warnings were issued for Oklahoma and the northern portion of west Texas and were extended the following morning over northwestern Arkansas, northern east Texas, and southern west Texas. On 1 p. m. special observations the warning was further extended over the remainder of Arkansas and the southwestern portion of east Texas, and at night over northern and western Louisiana and the southeastern portion of east Texas. On the morning of the 13th cold-wave warnings were extended over southeastern Louisiana. The warnings were fully verified except at El Paso, where the lowest temperature was about freezing. Over most portions of the district, temperatures were about as low as they were during the cold wave of the 9th–10th and agreed closely with the minimum temperatures forecast, as in the case of the 9th–10th.

Warnings were issued at night on the 30th for a cold wave in the northwestern portion of the district, and on the morning of the 31st the warnings were extended over Arkansas. The cold wave occurred as forecast, except in the Texas Panhandle, where the temperature did not go below 20°, due to a division of the area of high pressure, the main part lagging behind the part which was following a trough of low pressure moving northeastward from the middle Mississippi Valley.

Forecasts of minimum temperatures and weather conditions attending the cold waves of this month proved to be of timely value to stockmen and others. The forecast distributor at Garden City, in the southeastern portion of west Texas, states that the "special warnings are proving useful and helpful to stock raising and farming interests." The following is quoted from a letter dated Hope, Ark., December 13, 1919, from the Hope Brick Works, receiving "collect" messages of minimum temperature forecasts on request:

> The message you sent us Monday afternoon of this week caused us to save about $1,200 to $1,400 worth of brick that would otherwise have been lost.

Warnings of frost or freezing temperature for the coast and adjacent areas were issued on the 10th, 14th, 15th, 16th, 24th, 25th, 26th, 27th, and 29th, and were generally verified.

Fire-weather warnings for the forest reserves of Arkansas and Oklahoma were issued on the 12th and 31st and were verified.—*R. A. Dyke.*

Denver Forecast District.—The weather during the early part of the month was dominated by Pacific LOWS, and precipitation occurred in some part of the district nearly every day. During this period sharp changes in temperature were a feature of the weather in the more eastern parts of the district, under the influence of Alberta anticyclones which skirted the eastern slope. After the storm of the 12th, however, strong anticyclonic conditions became established in the Plateau region and continued with more or less intensity during the remainder of the month. Abnormally low temperatures resulted on the western slope, and the temperature at Grand Junction and Salt Lake City was below the normal almost continuously after the 12th. This pressure distribution was attended on the eastern slope by the usual type of weather—mild temperature and fair weather, with at times a pronounced chinook effect. Moreover, fair weather prevailed generally throughout the district during the remainder of the month, except on one or two dates in parts of New Mexico.

Cold-wave warnings were issued for eastern Colorado on the morning of the 1st and for eastern New Mexico on the evening of that date. The warnings were followed by subzero (F.) temperatures in eastern Colorado and a sharp fall in temperature in southeast New Mexcio. On the evening of the 7th cold-wave warnings were issued for nearly all of eastern Colorado, with warnings of heavy snow in Utah, strong westerly winds in Arizona, and much colder weather in eastern New Mexico by the 9th. The cold wave overspread eastern Colorado on the 8th, while heavy snow occurred in eastern Utah and adjacent portions of Colorado and fresh to strong winds prevailed in Arizona and parts of southern Utah and western New Mexico. On the morning of the 8th cold-wave warnings were extended to include Utah, western Colorado, northern and central Arizona, and northern and eastern New Mexico, and repeated on the evening of the 8th for New Mexico. In Colorado the temperature fall on the morning of the 9th ranged from 15 to 40 degrees (F.). At Pueblo the temperature fell to 20° (F.) below zero, the lowest of record at that station for December, while at Grand Junction the lowest temperature ever recorded there was reached on the 9th. Subzero temperatures occurred in Utah, northern Arizona, and New Mexico. Warnings of fresh to strong westerly winds were issued for Utah on the morning of the 11th and for Colorado on the evening of that date. Wind velocities exceeding 40 miles per hour from a westerly direction were reported at Modena, Salt Lake City, and Pueblo. At Denver the highest velocity recorded was 38 miles per hour from the north.

Cold-wave warnings were issued for the district on the 12th and repeated on the evening of the 12th and morning of the 13th for parts of New Mexico, a depression of marked intensity being central in southeast Colorado. The fall in temperature in eastern Colorado was even greater than during the cold wave of the 9th but the minima were not so low. No other cold-wave warnings were issued after the 13th, except for eastern Colorado at the close of the month. While this warning failed of verification, a fall in temperature of 20 degrees or more occurred with temperatures 10 degrees or more below the freezing point.—*Frederick W. Brist.*

San Francisco Forecast District.—Rain fell in California during the fore part of the month, which was caused by a weak low-pressure area overlying that State. This depression moved so slowly eastward that it affected the weather in this district for five or six days. It was followed on the 9th by another depression of decided character, which was first noted along the Oregon coast. It moved slowly southeastward and not only caused rain in California but considerable snow in western Oregon and western Washington. It was not until December 12th that its influence was no longer felt in this district. On this date a high-pressure area advanced south from British Columbia to the North Pacific States and caused much colder weather in that section of this district. This cold wave lasted several days.

About the middle of the month the pressure over the central Plateau States became unusually high and the lows therefore passed eastward too far north to materially affect the weather in California or Nevada. They, however, caused occasional rain, high winds, and warmer weather in the North Pacific States.

The presence of the high-pressure area over the central Plateau States caused cold-air drainage into California, and frosty mornings were of almost daily occurrence. The frosts did no great damage, as almost all the staple crops had been harvested before they occurred. In southern California the frosts were not so severe as they were farther north, and the orange and lemon crops on this account escaped serious injury.

No less than 23 frost warnings were issued for places in California and practically all of them were verified. Storm warnings were issued for different parts of this district on 18 occasions, and small-craft warnings were displayed on three days.

Only one cold-wave warning was issued, though more than one cold wave occurred. The others, in which the falls in temperature were sufficient to justify a cold-wave warning, in several instances were covered by predictions of colder or much colder weather, because the drop in temperature was somewhat greater than expected.

Generally the northern high-pressure areas that cause cold waves move into the United States east of the Rocky Mountains and therefore only slightly affect the weather in this district, but this year several moved directly south from British Columbia to the North Pacific States and thereby caused persistently low temperatures throughout this district for several days at a time.—*E. A. Beals.*

NORTHER IN THE CANAL ZONE.

The following letter, dated January 8, 1920, from the office of the chief hydrographer of the Canal Zone refers to the warning for "fresh to strong northerly winds next 36 to 48 hours" sent that office on the 29th:

> The warning was timely and fully verified. The wind reached a maximum velocity of 30 miles an hour from the northeast on the 30th at Cristobal, with gusts up to 45 miles reported from the naval air station. Cape Mala reported maximum winds up to 60 miles an hour. Windy weather continued for several days.
>
> In addition to serving the shipping interests, the naval air station at Coco Solo considers these warnings beneficial and necessary.

RIVERS AND FLOODS, DECEMBER, 1919.

By A. J. HENRY, Meteorologist.

DAMAGING FLOODS IN THE EAST GULF STATES.

Light rains fell in the northern portion of Mississippi, Alabama, and Georgia and in Tennessee on the 6th. These were followed by heavy rains on the 7th, especially in northern Alabama and northwest Georgia, and these in turn by still heavier rains on the 8th and 9th practically throughout Alabama and northwest Georgia. The rains ceased before midnight of the 9th. The daily amounts for representative stations in Mississippi, Alabama and Georgia are shown in Table No. 1 below. In Table 2 the rainfall for all stations in the Chattahoochee and other river basins in Georgia are given. These tables show that the intensity of the rains was greatest in northern Alabama on the 7th, southeastern Mississippi on the 8th, and central Alabama and northwest Georgia on the 9th. The rainfall was not uniformly heavy at all stations, the maximum for the 3 days being as much as 12 inches in local areas. From these areas as a center the fall diminished to the northwest and the southeast to 4 to 6 inches and even less.

TABLE 1.—*Daily precipitation (inches and hundredths—Midnight to midnight).*

1919.	Meridian.	Montgomery.	Birmingham.	Chattanooga.	Atlanta.	Augusta.
Dec. 7	2.54	2.20	4.12	0.81	2.70	0.70
8	6.75	1.64	3.39	1.24	3.34	.39
9	1.11	4.78	.81	.71	5.71	T.
Total	10.40	8.62	8.32	2.76	11.75	1.09

TABLE 2.—*Rainfall of Dec. 7 to 10, 1919, in Georgia.*

[Measurements made about 5 p. m., except at stations otherwise indicated.]

WATERSHED OF THE CHATTAHOOCHEE RIVER.

Stations.	Dec. 7.	Dec. 8.	Dec. 9.	Dec. 10.	Total.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Dahlonega	0.81	1.08	3.74	1.53	7.16
Gainesville	0.90	1.35	2.20	3.00	7.45
Canton	0.97	1.93	4.57	1.93	9.40
Norcross[2]	1.10	1.62	4.92	5.22	12.86
Atlanta[1]	2.70	3.34	5.71	.00	11.75
Lost Mountain	1.40	2.15	4.68	0.79	9.02
Newnan	1.01	1.80	2.12	4.20	9.13
West Point	0.24	2.70	3.33	2.50	8.77
Goat Rock	0.06	1.58	2.75	2.51	6.90
Talbotton	1.45	2.00	0.93	1.09	5.47
Columbus	0.04	0.08	2.48	0.87	3.42

[1] Measurements midnight to midnight.
[2] Measurements made daily at 7 a. m. mean local time.

TABLE 2.—*Rainfall of Dec. 7 to 10, 1919, in Georgia*—Continued.

WATERSHED OF THE FLINT RIVER.

Stations.	Dec. 7.	Dec. 8.	Dec. 9.	Dec. 10.	Total.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Atlanta[1]	2.70	3.34	5.71	0.00	11.75
Newnan	1.01	1.80	2.12	4.20	9.13
Griffin	0.00	5.08	1.33	3.00	9.41
Woodbury[2]	0.00	1.94	1.36	2.16	5.46
Butler	0.00	0.00	1.92	0.67	2.59
Marshallville	T.	T.	1.17	0.50	1.67
Talbotton	1.45	2.00	0.93	1.09	5.47
Montezuma[2]	0.00	0.00	0.25	0.95	1.20
Americus	0.00	0.00	0.10	0.52	0.62
Albany	0.00	0.15	0.00	0.07	0.22
Bainbridge	0.06	0.00	1.94	0.00	2.00

UPPER WATERSHED OF THE OCONEE AND OCMULGEE RIVERS.

Stations.	Dec. 7.	Dec. 8.	Dec. 9.	Dec. 10.	Total.
Atlanta[1]	2.70	3.34	5.71	0.00	11.75
Griffin	0.00	5.08	1.33	3.00	9.41
Covington	0.90	3.60	1.90	3.60	10.00
Macon[1]	0.14	1.43	0.08	0.31	1.96
Athens	0.76	2.52	2.81	3.80	9.89
Greensboro		5.39			
Milledgeville[2]	T.	0.82	1.10	0.50	2.42

UPPER WATERSHED OF THE SAVANNAH RIVER.

Stations.	Dec. 7.	Dec. 8.	Dec. 9.	Dec. 10.	Total.
Clayton					
Toccoa	0.78	0.99	3.32	3.82	8.91
Hartwell	0.87	1.68	3.78	1.24	7.57
Carlton	0.50	1.95	2.30	2.79	7.54
Point Peter					8.00
Lisbon	0.80	5.78	0.35	0.10	7.03
Washington	0.37	3.00	2.80	0.53	6.70
Augusta[1]	0.70	0.39	T.	0.36	1.45

[1] Measurements midnight to midnight.
[2] Measurements made daily at 7 a. m. mean local time.

The meteorological conditions associated with or responsible for these rains were in no wise remarkable, but the sequence in which they developed was the controlling factor. Stripped of all technical language, it may be said that the rainstorm of the 6th–7th was immediately followed by one of somewhat greater intensity which passed over the East Gulf States from west to east on the 8th–9th. The rainfall on the dates last named produced damaging floods in all streams of southeastern Mississippi, Alabama, and Georgia. The flood in the Alabama, at Montgomery and Selma, closely approached the greatest flood experienced within historic times, viz, that of April 1, 1886. The flood on the Black Warrior River at Tuscaloosa, however, fell

12 feet short of the greatest flood hitherto recorded. The flood on the Tallapoosa, of Alabama, was the greatest recorded since the beginning of observations in 1903. Serious inconvenience and distress was caused at Montgomery, Ala., by the flood waters. The overflow penetrated the city supply of drinking water, got into the machinery of the municipal power and light plants, and caused a shut down of all power and light service. Railway train service was also interrupted and cellars were flooded in a large part of the city.

Despite the early and repeated warnings, it was necessary to rescue by boat many people who had become marooned on points of high ground near the river. Five persons in Montgomery lost their lives in the flood through the overturning of small boats. The total loss of life elsewhere in the flooded districts was 14.

Table 3 has been prepared for the purpose of comparing the 1919 flood with previous floods. The table gives the highest known water and the stages of 6 of the great floods during recent years. The dates of the floods were selected with reference to the Montgomery record. It was subsequently enlarged to include the floods of 1912 and 1913, which were more severe in the rivers of Georgia than in those of Alabama, and on the other hand the floods of 1906 and 1909 were less severe in Georgia than in Alabama.

TABLE 3.—*Flood in East Gulf States, December, 1919.*

River and station.	Previous high water.	Date.	High water in flood of—							
			January, 1892.	March, 1906.	March, 1909.	March, 1912.	March, 1913.	July, 1916.	December, 1919.	Above or below previous high water.
	Feet.		*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Chicasawhay:										
Enterprise, Miss...	36.0	May 27, 1909	.....	29.4	36.0	27.1	23.6	28.1	36.0	− 0.2
Black Warrior:										
Tuscaloosa, Ala ...	68.6	Apr. 18, 1900	59.9	59.3	63.8	57.2	58.2	66.3	56.6	−12.0
Coosa:										
Lock No. 4, Ala...	24.1	July 16, 1916	.....	22.2	22.7	18.5	16.5	24.1	18.3	− 5.8
Wetumpka, Ala...	61.7	Apr. 1, 1886	.....	51.5	51.3	44.8	46.4	51.5	55.6	− 6.1
Tallapoosa:										
Millstead, Ala.....	48.2	Mar. 16, 1912	.....	42.8	42.2	48.2	44.0	39.8	[1]54.0	+ 5.8
Alabama:										
Montgomery, Ala..	59.7	Apr. 1, 1886	54.0	50.2	51.7	44.9	48.1	51.7	57.1	− 2.6
Selma, Ala.........	57.0	Apr. 8, 1886	54.0	50.2	52.9	46.4	49.4	53.9	55.9	− 1.1
Chattahoochee:										
Norcross, Ga.......	19.7	July 11, 1916	.....	.....	.....	19.3	12.7	19.7	27.1	+ 7.4
West Point, Ga....	25.6	Mar. 31, 1886	.....	18.7	19.2	22.9	18.3	22.0	29.3	+ 3.7
Columbus, Ga.....	48.5	Mar. —, 1886	.....	.....	.....	.....	.....	41.9	52.0	+ 3.5
Eufaula, Ala.......	56.0	Mar. 28, 1888	.....	36.2	41.8	48.3	54.5	52.4	53.4	− 2.6
Alaga, Ala.........	44.0	July 9, 1916	.....	29.7	35.3	38.9	40.2	44.0	40.7	− 3.3
Flint:										
Albany, Ga........	32.4	Mar. 25, 1897	.....	13.7	22.4	30.2	30.3	27.3	24.2	− 8.2
Oconee:										
Dublin, Ga........	25.8	Mar. 5, 1902	.....	17.5	23.3	25.2	26.5	16.5	24.0	− 1.8
Ocmulgee:										
Macon, Ga.........	24.0	Aug. —, 1887	.....	17.0	20.4	22.7	23.6	23.1	25.3	+ 1.3
Savannah:										
Augusta, Ga.......	38.8	Aug. 27, 1908	32.8	28.6	28.0	36.8	35.1	28.4	35.4	− 3.4

[1] Estimated.

The following detailed description of the flood in rivers of Georgia has been supplied by Meteorologist C. F. von Herrmann, in charge of the Atlanta station of the Weather Bureau.

The area of heaviest precipitation was central in Fulton, Gwinett, and DeKalb Counties in northern Georgia, Norcross, in Gwinett County, receiving 12.86 inches in four days and Atlanta 11.75 inches. From this center the precipitation rapidly diminished toward the southeast and northwest, but extended from southwest to northeast over practically the entire watershed of the Chattahoochee River from Columbus to its most northern tributaries, and covered to a less extent the upper basins of the Flint, Oconee, Ocmulgee, and Savannah Rivers, as well as the tributaries of the Coosa, which join at Rome, Ga. Table 2 gives the actual rainfall over the most important watersheds.

Several noteworthy features concerning the December, 1919, floods at once attract attention. The heaviest rainfall must have covered a comparatively narrow stretch of country along the Chattahoochee from north of Columbus to Norcross, a distance of some 160 miles. This is made evident by the fact that the crest stages in the river at all three points, Norcross, West Point, and Columbus, were attained on the same day, and not only on the same day, but approximately about the same hour, namely, between 2 and 4 p. m. on December 10. In other words, the crest stages were caused by the water that entered the river in the immediate vicinity of each river station, rather than by the progress of the flood wave from upper to lower stations. Thus the very heavy rainfall telegraphed on the morning of December 10, covering the watershed from West Point northward, which, under ordinary circumstances, would have caused the steady movement of a crest from Norcross to Columbus during the next three days, had practically no further effect on the rivers already far above flood stage at all points and therefore spread out in many places to a width of 2 or 3 miles. Consequently, the flood in the Chattahoochee River was rapid, destructive, giving at two of the upper stations unprecedented high stages, which were maintained for an unusual duration of time. Thus the stage at Eufaula, Ala., remained above 50 feet (flood stage 40 feet) for no less than four days, from December 12 to 15, inclusive.

On the other hand, the absence of any considerable rainfall over the lower watershed of the Flint River gave rise to a very slow progress of a distinct flood crest from Woodbury, where it occurred on December 11, to Bainbridge on December 20, four days after the flood waters had swept out of the Chattahoochee.

The Savannah River at Augusta reached a stage of 35.4 feet on December 10, which is 3.4 above the flood stage, and may be compared with the high record of 38.8 feet in 1908. Owing to the great concrete levee separating the city from the flood waters the streets of Augusta, which formerly were badly flooded at stages as high as 34 feet, were quite dry, and no great damage occurred.

The flood in the upper Ocmulgee at Macon was severe. On December 11 and 12 the river was a raging flood, with an estimated velocity of 25 miles an hour. At 5.55 p. m. on December 12 the gage showed a crest stage of 25.3 feet, exceeding the preceding highest record by 1.3 feet. The lowlands on the east side of the river were entirely submerged and several houses were carried away, but as the authorities had been notified to move the inhabitants to the highlands no loss of life is known to have occurred. Many families had to camp out on high ground with the household effects that could be saved. The water was several feet deep over the Southern Railway near the Spring Street bridge and fears were entertained for the safety of the bridge, which was closed to traffic. The flood endangered the city water plant, but about 2 p. m. on December 11, the levee that protects Central City Park gave way, leaving a crevasse about 300 feet wide. This relieved the danger to some extent, for while the park and the Macon, Dublin & Savannah Railroad tracks were submerged, the backing up of the water below was to some extent prevented, and much property was saved that would otherwise have been lost. Great damage was done to the Central City Park and to the buildings and property of the State Fair Association.

The rise in the Flint River was not dangerous except in the extreme upper part of the watershed. Warnings were issued so far in advance of the flood wave for all points below Woodbury that there was ample time to take necessary precautions. At Woodbury the Flint attained an unprecedented stage of 17.1 feet on December 11. The crest was attained at Montezuma on the 13th, at Albany on the 18th, and at Bainbridge, where however, the flood stage was not quite reached, on the 20th. No great amount of damage was caused by the flood.

The Coosa River at Rome attained a stage of 32.8 feet on the 11th, as compared with a previous maximum stage at Rome of 40.3 feet in 1886. At Canton, on the Etowah, however, a crest stage of 24.3 feet was registered, which surpassed the previous maximum record of 23.9 feet in July, 1916. Some damage occurred at Rome to manufacturing plants near the river, water entered the basements of some houses, and a number of people had to move out of their homes.

THE FLOOD IN THE CHATTAHOOCHEE.

The rise in the Chattahoochee River north of Columbus surpassed all previous records in the history of the river. The increasing frequency of floods in the Chattahoochee River during the last 20 years as compared with the period of 20 years immediately preceding is very striking. At Norcross, some 20 miles north of Atlanta, the Chattahoochee River reached a crest stage of 27.1 feet at about 3 p. m. on December 10, or 7.4 feet higher than the July, 1916, record. This extraordinary rise imperiled the waterworks system of the city of Atlanta by threatening to flood the pumping station. The river attained a height of 5.9 feet above the top of the permanent dikes that protect the plant, and the danger was only averted by the strenuous efforts of laborers, volunteer workers, and convicts summoned by the county officials who, for 48 hours, piled hundreds of tons of clay and sand bags on top of the dikes to keep it above the rising flood. By the evening of December 10 the danger was past.

There can be no doubt that the greatest destruction occurred at the city of West Point, which is situated at the point where the Chattahoochee River begins to form the boundary between Georgia and Alabama. This is a thriving city of cotton mills and manufacturing plants, the business part of the city and many residences being built on the low ground near the river banks between the hills on the eastern and western banks of the river. At a stage of 22 feet the water enters the streets of the city; the sidewalks and stores are elevated above the streets proper some 3 or 4 feet. This place having experienced a rise to 25.6 feet in 1886 and again to 25 feet in December, 1901, merchants are prepared to elevate their goods to higher positions in the stores when floods are threatened. The river, however, on this occasion rose with such rapidity and reached such an unprecedented stage that in many cases the precautions taken were of no avail. The crest reached at West Point was 29.3 feet on the afternoon of December 10.

The entire business section of West Point was flooded. Manufacturing establishments, hotels, the Auditorium, churches, warehouses, general stores, and numerous residences were surrounded by a swiftly moving current of water from 5 to 10 feet deep. There was no loss of life, but several hundred people were marooned for some days. The highway bridge over the Chattahoochee which connects the two sides of the city and supported the big water main was carried away, so that the city was without drinking water. The telephone and electric-light systems, gas works, and street-car service were entirely put out of commission, entailing great loss to equipments. The loss of property as a whole, though not yet accurately fixed, is conservatively estimated to have exceeded a million dollars. For some days following the flood the distress at West Point was so great that Red Cross aid from Atlanta was rushed to the city and contributions of money poured in from neighboring cities.

The Chattahoochee at Columbus rose to the very high stage of 52 feet, surpassing the record of 1886 by 3.5 feet. A great deal of damage was done to the machinery and stock of the cotton mills, iron foundries, grocery stores, and other commercial concerns along the river front. Electric light and street car service were suspended, and gas for cooking could not be obtained for some days. At Girard across the river in Alabama poorer people living in lowlands near the river had to vacate their homes. There was much enforced idleness owing to the impossibility of operating the mills.

Another feature of the flood was the enormous loss of river and smaller county bridges in at least a dozen counties within the region of greatest precipitation. The following counties suffered most severely: Fulton, Cobb, DeKalb, Rockdale, Spalding, Hall, and numerous others. On the night of December 9 while endeavoring to cross Utoy Creek near Atlanta an automobile was precipitated into the flooded creek, and three persons were drowned. The loss to crops gathered or prospective was very small, and to railroad property not great. An estimate of the total loss, including loss to buildings, factories, municipal plants, highways, and bridges, may conservatively be placed at nearly $2,000,000.

FLOODS IN THE MERIDIAN, MISS., RIVER DISTRICT, DECEMBER, 1919.

By J. H. JAQUA, Observer.

From December 8 to 9, 1919, more than 10 inches of rain fell over a narrow strip of territory in Mississippi, averaging approximately 50 miles in width, and extending northeastward from Lincoln County, in the southern portion of the State, to Kemper County, in the east-central portion, a distance of about 150 miles. The greatest depth of rainfall, somewhat over 12 inches, was in Lincoln and Lawrence Counties. To the northward and to the southward of the 10-inch area, the isohyets decrease rapidly to less than 4 inches. As the principal tributaries of the Chickasawhay, the Leaf, and lower Pearl Rivers originate in the region covered by excessive rains, the rise was extraordinary and unusually destructive in the upper watersheds of those streams.

The rise in the two uppermost reaches of the Chickasawhay River, Sowashee Creek and Chunky Creek, was the greatest of record. According to reliable marks, the overflow of Sowashee Creek, at Meridian, on the 8th–9th, was about 16 inches above any previous known mark, but southward from Meridian and from Chunky, on Chunky Creek, the crest stages were progressively lower than in the record flood of April, 1900. The stages in the upper Chickasawhay were from 8 to 12 inches below the heights reached in April, 1900, and were generally slightly lower than the stages reached in May, 1909.

Sowashee Creek, which is usually an insignificant stream, became, on the night of the 8th, a raging river of no mean proportions, threatening destruction to a large area in Meridian and its suburbs. The lower levels of the city and the districts to the southward were inundated until noon of the 9th. In this district it was necessary to transport hundreds of Negroes to higher ground, many of the victims being awakened by rescuers when the rising waters had already entered their dwellings. One person was drowned in rescue work.

The losses to individuals were not large in the aggregate, but many of the poorer families lost their hogs, chickens, and, in a few instances, their household effects.

All railroads in Lauderdale County suffered heavily by washouts, suspending traffic for two days. Many county bridges were washed out, and the damage to hard-surfaced roads was considerable, especially in the direction of Arundel. About three-fifths of the loss in the Meridian section is represented by damage to buildings, highways, and bridges.

Damage in the Chickasawhay Valley.—The crest stage reached at Enterprise was 37 feet, at 1 a. m. of the 10th, or 1 foot below the record stage. On the night of the 8th, the merchants began to elevate their stocks of goods to levels above average high water, but in spite of these precautions much damage was done to merchandise in storehouses.

The rise at Shubuta was 11.4 feet during the night of the 8th to a stage of 33 feet at 7 a. m. of the 9th, and at 1 p. m. of the 11th a crest stage of 44.3 feet was reached. As it was impossible, after 7 a. m. of the 9th, to reach the bridge upon which the river gage is located, the crest reading was derived by comparison with the record water mark of 45 feet, in April, 1900, the recent stage being about 8 inches lower.

Great damage occurred in the districts between Enterprise and Shubuta. Most of the inhabitants of lowlands suffered severely, somewhat more than 200 families, chiefly colored, near Shubuta, being obliged to abandon their homes, which were flooded to depths ranging from 3 to 4 feet for about two days. These families lost nearly all of their corn, peas, potatoes, and live stock, in addition to damage to household effects. It appears that the greater portion of the losses could have been avoided had the sufferers heeded the warnings, which were two days in advance of the flood. The river observer at Shubuta states that, "still with all the warnings they would not believe that it would be as it proved to be."

Railroad washouts were numerous along the Chickasawhay. In some instances from 300 to 500 feet of roadbed were undermined. Traffic was suspended for two days and complete resumption was not accomplished for nearly 10 days after the water receded. The Mobile & Ohio Railroad Co., by "tieing" its tracks at critical points, avoided the disaster of April, 1900, when their tracks were hurled into the woods for much of the distance from Meridian southward.

From Shubuta southward, the damage was less severe than in Clarke County, but there was a heavy loss of live stock and lumber, and great damage to roads, creek bridges, and fences.

Leaf River district.—The Leaf River, at Hattiesburg, reached a crest stage of 25.3 feet on the 11th, the highest since regular readings began. The loss by overflow and backwater at Hattiesburg and adjacent localities was probably greater than in any other section of equal area.

The inundated area averaged eight blocks from the river in the northern and eastern sections of the city, dwellings being flooded from 2 to 3 feet deep. In the sections occupied largely by Negroes, about 400 families were compelled to abandon their homes. The number of refugees was approximately 1,000; these were cared for by public relief associations. Three persons are known to have lost their lives by drowning.

Nearly every factory in the district suffered losses ranging from $500 to $35,000, the principal product damaged being dry lumber, and there was also considerable loss through suspension of business. Below Hattiesburg the chief losses were due to drowning of live stock, the washing away of logging roads, bridges, and portions of highways.

In Jones County all railroads were washed badly, suspending traffic for two or three days. Near Laurel many families had to abandon their homes, and some residents had narrow escapes from drowning.

Two railroad wrecks, due to washouts, occurred on the Mississippi Central, the first one on the 8th, about 2 miles west of Hattiesburg, where the engine was derailed, killing the engineer instantly. The second wreck was on the 9th, near Prentiss, where an extra freight train went through a trestle that had been damaged by high water. The fireman was buried under the locomotive.

Pascagoula River district.—At Merrill, at the head of the Pascagoula River, there was a rise of 7.8 feet, on the 8th, to 20.5 feet, on the 13th, when the flood waters from the Chickasawhay and Leaf Rivers began to arrive. On the 15th, a crest stage of 25.5 feet was reached. This is the highest stage since the record of 27 feet on July 9, 1916.

In Greene, George, and Jackson Counties, more than 1,000 head of cattle were drowned and the lumbering industry was stopped.

Pearl River district.—The rainfall over the watershed of the Pearl River above Jackson was much less than it was over the districts below Jackson and in the eastern portion of the State. A crest of 23.3 feet was reached at Edinburg, on the 12th, and 30.5 feet, at Jackson, on the 17th. In the Pearl River valley north of the Alabama & Vicksburg Railroad the losses by overflow were generally unavoidable and not unusual. The greater losses were due to freshets in the creeks tributary to the main stream. Small bridges were dislodged and logging roads washed out, but there was no material damage done to improved highways. Railroads in this section suffered little.

From Jackson south nearly to the line of the Mississippi Central Railroad there was no extraordinary overflow, although truck crops at Crystal Springs were damaged considerably.

In the counties of Lincoln, Lawrence, Marion, and Pearl River, the water stages were nearly equal to those reached in the historic flood of April, 1900. A large number of both wooden and steel bridges were dislodged. and for the first time since April, 1896, the tracks of the Illinois Central Railroad Co., near Bogue Chitto, Miss., were submerged for a distance of 3 to 4 miles. Considerable damage was done to recently constructed gravel roads in Lincoln County. It is also reported that the loss by erosion in the counties named was extensive and probably will cause the abandonment of large cultivated areas. About 500 acres of oats were flooded.

The West Pearl River.—In the county of Walthall, Miss., and in the parishes of Washington and St. Tammany, La., which are traversed by Bogue Chitto River, great damage was sustained to highways and sawmills. The loss of livestock was probably the greatest of the last 20 years.

In addition to the heavy loss of live stock in the West Pearl bottoms, there was extensive damage to logging roads. The probable loss of many logging teams was prevented by their timely withdrawal.

Estimated loss due to floods, December, 1919.

Rivers of—	Tangible property, bridges, roads, etc.	Crops.		Live stock and other farm property.	Suspension of business.
		Gathered.	Prospective.		
Mississippi (southeast)	$435,000			$144,000	$104,900
Alabama	1,637,600	$638,000	$32,100	82,150	22,500
Geor ia	2,000,000				
South Carolina				760	760
Total	4,072,600	638,000	32,100	226,910	128,160

Flood stages, December, 1919.

Drainage, river, and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
ATLANTIC DRAINAGE.					
Santee:	*Feet.*			*Feet.*	
Rimini, S. C	12	11	21	15.2	16
Ferguson, S. C	12	13	23	13.7	17, 18
Saluda:					
Chappells, S. C	14	9	14	19.5	12
Pelzer, S. C	7	10	11	14.0	9
Savannah:					
Calhoun Falls, S. C	15	11	11	15.0	11
Augusta, Ga	32	10	12	35.4	11
Broad:					
Carlton, Ga	11	9	11	28.0	10
Oconee:					
Millegeville, Ga	22	10	13	31.4	12
Dublin, Ga	22	15	16	24.0	15
Ocmulgee:					
Macon, Ga	18	10	13	25.3	11
Hawkinsville, Ga	29	15	15	29.3	15
Abbeville, Ga	11	15	22	16.5	17
Lumber City, Ga	15	20	22	16.5	21
EAST GULF DRAINAGE.					
Flint:					
Woodbury, Ga	10	10	13	17.1	11
Albany, Ga	20	16	19	24.2	17
Chattahoochee:					
Norcross, Ga	16	10	11	27.1	10
West Point, Ga	20	9	?	29.3	10
Columbus, Ga	20	?	?	52.0	10
Eufaula, Ala	40	11	16	53.4	14
Alaga, Ala	30	11	17	40.7	14
Alabama:					
Montgomery, Ala	35	10	18	57.1	11
Selma, Ala	35	10	20	55.9	14
Talapoosa:					
Milstead, Ala	40	10	12	54.0	10
Coosa:					
Rome, Ga	30	11	11	32.8	11
Gadsden, Ala	22	14	16	22.8	15, 16
Lock No. 4, Lincoln, Ala	17	10	17	18.3	11
Wetumpka, Ala	45	10	14	55.6	12
Etowah:					
Canton, Ga	11	9	11	24.3	10
Cahaba:					
Centerville	25	9	11	32.8	
Tombigbee:					3
Aberdeen, Miss	33	3	3	33.0	19
Demopolis, Ala	39	9	24	58.1	6
Black Warrior:					
Tuscaloosa, Ala	46	9	12	56.6	10
Pascagoula:					
Merrill, Miss	20	13	20	25.5	15
Chickasawhay:					
Enterprise, Miss	21	9	12	36.2	10
Shubuta, Miss	27	9	16	44.3	12
Leaf:					
Hattiesburg, Miss	19	10	13	25.3	11
Pearl:					
Edinburg, Miss	20	11	15	23.3	17
Jackson, Miss	20	9	27	30.5	12
Columbia, Miss	18	9	28	25.6	12
West Pearl:					
Pearl River, La	13	13	(1)	16.3	13

1 Continued into January.

Flood stages, December, 1919—Continued.

Drainage, river, and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
OHIO DRAINAGE.					
Little Kanawha:	*Feet.*			*Feet.*	
Glenville, W. Va	22	7	7	23.9	7
Ohio:					
Cloversport, Ky	40	11	19	44.8	14, 15
Henderson, Ky	33	1	23	40.4	16, 17
Evansville, Ind	35	1	23	42.3	16, 17
Mount Vernon, Ind	35	3	24	41.5	18
Shawneetown, Ill	35	3	24	42.1	18, 19
Scioto:					
Circleville, Ohio	7	1	1	8.5	1
Licking:					
Farmers, Ky	25	7	7	25.0	7
South Fork of Licking:					
Cynthiana, Ky	20	7	7	21.0	7
Green:					
Lock No. 4, Woodbury, Ky	33	(1)	3	39.5	1
Do	33	9	19	39.5	17
Lock No. 2, Rumsey, Ky	34	(1)	25	40.7	20
Wabash:					
Lafayette, Ind	11	1	1	11.7	1
Mount Carmel, Ill	15	4	7	15.8	5
North Fork of Holston:					
Mendota, Va	8	14	14	10.5	14
Tennessee:					
Riverton, Ala	32	15	15	32.3	15
MISSISSIPPI AND GULF DRAINAGE.					
St. Francis:					
Marked Tree, Ark	17	(1)	27	17.6	15–21
Mississippi:					
Arkansas City, Ark	42	13	(2)	44.3	27, 28
Yazoo:					
Yazoo City, Miss	25	15	(2)	27.7	30, 31
Tallahatchie:					
Swan Lake, Miss	25	4	(2)	28.7	15–16
Atchafalaya:					
Melville, La	37	27	(2)	37.1	30, 31
Black:					
Black Rock, Ark	14	(1)	5	16.6	1
Cache:					
Jelks, Ark	9	(1)	26	10.3	14, 15
Sulphur:					
Finley, Tex	24	3	6	25.0	4
Ringo Crossing, Tex	20	(1)	4	21.8	1
Trinity:					
Liberty, Tex	25	(1)	6	28.2	[3]30, No. 2
Dallas, Tex	25	(1)	2	34.2	[3]30
Trinidad, Tex	28	1	9	34.6	6

[1] Continued from November. [2] Continued into January. [3] November.

Flood stages, December, 1919—Continued.

Drainage, river and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
MISSISSIPPI AND GULF DRAINAGE—Continued.					
Sabine:	*Feet.*			*Feet.*	
Bon Weir, Tex	20	11	15	20.2	13, 14
PACIFIC DRAINAGE.					
Gila:					
Kelvin, Ariz	5	5	8	10.0	5
Willamette:					
Eugene, Oreg	10	11	11	12.0	11
Oregon City, Oreg	10	22	27	10.8	22

MEAN LAKE LEVELS DURING DECEMBER, 1919.

By UNITED STATES LAKE SURVEY.

[Dated Detroit, Mich., Jan. 6, 1920.]

The following data are reported in the "Notice to Mariners" of the above date:

Data.	Lakes.[1]			
	Superior.	Michigan and Huron.	Erie.	Ontario.
Mean level during December, 1919:	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Above mean sea level at New York	602.33	580.18	571.81	245.74
Above or below—				
Mean stage of November, 1919	−0.18	−0.25	−0.43	−0.37
Mean stage of December, 1918	−0.12	−0.85	−0.38	−0.15
Average stage for December, last 10 years	+0.03	+0.08	+0.12	+0.33
Highest recorded December stage	−0.80	−2.40	−1.72	−1.87
Lowest recorded December stage	+1.13	+1.18	+0.95	+2.31
Average relation of the December level to—				
November level		−0.2	−0.1	−0.2
January level		+0.2	+0.1	±0.0

[1] Lake St. Clair's level: In December, 574.62 feet.

EFFECT OF WEATHER ON CROPS, DECEMBER, 1919.

By J. WARREN SMITH, Meteorologist in Charge.

Advance of the season.—The first half of the month was unfavorable for outdoor activities in most sections of the country, especially in the Northwest, where it was unusually cold, with the ground mostly covered with snow. Frequent rains also hindered farm work in the lower Mississippi Valley and in many interior southern districts, but it was more favorable in the Southeast. After the middle of the month, weather much more favorable for seasonal farm work prevailed throughout the West, while the general absence of appreciable precipitation and stormy weather the latter part of the month was unusually favorable for field work in nearly all districts. The last week of the month was especially favorable from the upper Mississippi Valley and western Lake region westward to the Rocky Mountains. The roads and fields were muddy in the Southwest the first part of the month, and drifting snow delayed transportation in parts of the upper Mississippi Valley, while work in the cornfields was carried on with difficulty in most central districts. There was a general improvement in the conditions of the roads the latter part of the month, especially in northern States.

Small grains.—Winter grains were covered with snow throughout the month in the northern portions of the principal winter-wheat belt and the west-central portion was covered during most of the first half of the month. The extremely cold weather in the far Northwest during the first two weeks was unfavorable for winter grains, but the rainfall was beneficial in California, and seeding, which had been delayed by drought, was resumed in that State. Cold weather during portions of the month and alternate thawing and freezing at other times, in the absence of snow protection, damaged wheat in portions of the Ohio Valley, particularly in Kentucky and parts of the adjoining States. The lack of sufficient warmth and sunshine was also unfavorable for late-sown wheat in the extreme lower Great Plains. As a result of the warmer weather during the latter part of the month, the snow cover was greatly reduced, or entirely disappeared, in the far Northwest, but the melting was gradual and the soil mostly absorbed the resulting moisture. Winter grains, as a rule, made satisfactory advance in the Southern States, but some injury resulted to oats by frost in portions of the east Gulf area the latter part of the month.

Corn and cotton.—Further damage resulted to ungathered corn by continued rains in the lower Great Plains during the first part of the month, and conditions were unfavorable for husking in most sections until the last decade. The mild, dry weather permitted a resumption of this work in the upper Mississippi Valley during the last week of the month, while conditions were favorable in most other sections of the country where husking was not completed. Cotton picking was practically completed early in the month in the northeastern portion of the cotton belt; the yield of the late crop proved to be somewhat better than expected in portions of South Carolina. Cold, cloudy weather hindered picking in the northwest portion of the belt during the first half of the month, but this work made better progress under more favorable weather conditions during the latter part. Considerable cotton remained to be picked in Oklahoma at the close of the month.

Pastures, truck, and fruit.—The month was mostly favorable for pastures in the South. The first half was very unfavorable for stock in the North and Northwest, as it was extremely cold and the ranges were snow-covered. There was much suffering and considerable loss of stock in the upper Rocky Mountain and northern Great Plains districts as a result of the unfavorable weather conditions. Much of the range section was free of snow in the West and Northwest during the latter part of the month, however; grazing was possible in many localities, and stock showed a material recuperation, but much feeding was necessary in the Northwest on account of the poor range condition. The feed shortage resulted in heavy shipments of stock. Ranges were improved in the Pacific coast States by the rainfall of the month.

It was generally favorable for winter truck crops in the South, although frost did considerable damage to gardens in the west Gulf region and in northern Florida about the middle of the month. The latter part of the month was too cool for normal growth of truck crops along the south Atlantic coast and in Florida, but the lower temperatures were beneficial for the hardier truck in that State. Shipments of truck progressed from Florida, and good crops of cabbage and cauliflower were being harvested in California at the close of the month.

Citrus fruits colored nicely in Florida and strawberries were in fair condition, although the lower temperatures the latter part of the month unfavorably affected them. The month was generally favorable for citrus fruits in California, notwithstanding some damage resulted to oranges and olives in the central portion of the State by frost about the middle of the month. Cherry and peach buds were damaged in portions of Oregon by cold weather the latter part of the month, but at the same time citrus fruits were benefited in Florida by the cooler weather. At the close of the month the picking of oranges and lemons was progressing satisfactorily in California, with no serious frost losses reported.

CLIMATOLOGICAL TABLES.*

CONDENSED CLIMATOLOGICAL SUMMARY.

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, December, 1919.

Section.	Temperature.								Precipitation.					
	Section average.	Departure from the normal.	Monthly extremes.						Section average.	Departure from the normal.	Greatest monthly.		Least monthly.	
			Station.	Highest.	Date.	Station.	Lowest.	Date.			Station.	Amount.	Station.	Amount.
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	47.6	+ 1.2	2 stations	81	6†	Valley Head	12	15	7.30	+ 2.41	Talladega	15.35	Alaga	1.60
Arizona	44.8	+ 2.4	Avondale	83	27	St. Michaels	−18	9	0.61	− 0.55	Pinal Ranch	3.13	5 stations	0.00
Arkansas	40.4	− 1.6	Pine Bluff	78	30	4 stations	1	10†	1.96	− 2.07	Marianna	6.94	Ozark	0.06
California	46.1	− 0.6	King City	88	6	Portola	−19	12	3.87	− 0.16	Upper Mattole	14.00	2 stations	0.00
Colorado	23.4	− 1.9	Glendevey	72	17	Lay	−46	9	0.83	− 0.21	Cumbres	5.31	4 stations	T.
Florida	60.7	+ 1.2	2 stations	90	8†	5 stations	24	16†	2.73	− 0.16	Middleburg	7.13	Boca Grande	0.08
Georgia	48.2	+ 1.4	5 stations	85	9	Ramhurst	12	15	5.16	+ 0.94	Norcross	14.24	Savannah	0.12
Hawaii (November)	72.4	+ 0.6	Mahukona	94	3	Volcano Observatory	49	19	2.91	− 4.91	Pakaikou	12.37	Mahukona	0.00
Idaho	18.9	− 6.2	Indian Cove	66	4	Stanley	−50	12	1.51	− 0.33	McCall	3.85	Buhl	0.26
Illinois	24.0	− 6.2	Anna	65	31	Mount Carroll	−22	10	0.70	− 1.46	Shawneetown	2.54	Rushville	0.10
Indiana	25.6	− 6.7	Rome	63	31	Whiting	−15	10	1.39	− 1.32	Jeffersonville	6.11	Greencastle	0.02
Iowa	15.0	− 8.9	Lamoni	52	30	Thurman	−36	10	0.54	− 0.68	Earlham	1.55	Albia	0.08
Kansas	27.6	− 3.8	Liberal	76	30	St. Francis	−25	9	0.19	− 0.74	Republic	1.20	Emporia	0.00
Kentucky	34.6	− 2.5	Bowling Green	68	31	2 stations	3	10	4.93	+ 0.99	Mount Sterling	7.80	Beaver Dam	2.15
Louisiana	53.8	+ 1.9	Melville	80	6	Calhoun	16	14	3.04	− 2.33	Cheneyville	7.65	Paradis	0.30
Maryland-Delaware	30.6	− 3.9	2 stations	70	7†	Oakland, Md	−17	18	2.96	− 0.39	Friendsville, Md	4.34	Fairview, Md	1.47
Michigan	17.8	− 7.2	East Tawas	50	13	Iron River	−34	17	1.03	− 1.04	Houghton	5.67	Howell	0.10
Minnesota	7.6	− 8.0	Pine River Dam	66	24	Taylors Falls	−41	15	0.39	− 0.37	Chatfield	1.20	2 stations	T.
Mississippi	48.4	+ 1.1	Collins	85	7	Duck Hill	13	15	6.05	+ 0.93	Brookhaven	13.76	Crenshaw	1.40
Missouri	28.5	− 4.5	Hollister	74	30†	Tarkio	−22	10	0.69	− 1.50	Caruthersville	4.30	Trenton	0.02
Montana	16.4	− 7.0	Willow Creek Reservoir.	69	18	Bowen	−52	3	0.94	+ 0.11	Trout Creek	3.38	White Water	0.03
Nebraska	20.3	− 5.5	Auburn	64	30	2 stations	−36	9	0.58	− 0.16	Paxton	1.58	2 stations	T.
Nevada	29.6	− 1.9	Las Vegas	73	23	Elko	−26	9	1.26	− 0.03	Marlette Lake	7.25	Las Vegas	0.06
New England	21.3	− 4.5	Boston, Mass	61	13	Van Buren, Me	−39	17	1.95	− 1.42	Nantucket, Mass	3.67	Enosburg Falls, Vt.	0.88
New Jersey	28.8	− 4.1	2 stations	67	13	Culvers Lake	−18	18	2.98	− 0.84	Bridgeton	5.14	Boontown	1.84
New Mexico	37.1	+ 3.2	Pearl (near)	80	30	Dulce	−27	9	0.47	− 0.32	San Antone R. S.	2.60	10 stations	0.00
New York	21.4	− 5.1	New York City	60	13	Raquette Lake	−35	18	1.94	− 1.08	Adams Center	5.25	Avon	0.60
North Carolina	40.8	− 0.6	2 stations	80	9	2 stations	− 8	15	2.57	− 1.53	Highlands	9.49	Rougemont	0.10
North Dakota	7.4	− 5.6	Berthold Agency	49	29	Bottineau	−38	9	0.48	− 0.06	Cooperstown	1.30	2 stations	0.00
Ohio	25.7	− 5.2	Peebles	69	13	Summerfield	−12	20	2.13	− 0.80	Peebles	7.05	Napoleon	0.26
Oklahoma	35.6	− 3.6	Kenton	79	25	Hurley	−13	9	0.37	− 1.06	Hugo	2.84	2 stations	0.00
Oregon	30.2	− 6.8	2 stations	67	28	Blitzen	−47	12	4.19	− 0.28	Headworks	13.15	Andrews	0.99
Pennsylvania	25.3	− 5.2	Uniontown	66	9	West Bingham	−23	18	2.61	− 0.63	Somerset	4.75	2 stations	0.95
Porto Rico														
South Carolina	46.5	+ 2.0	Oaks	87	9	2 stations	15	16†	3.45	+ 0.06	Calhoun Falls	8.93	Blackville	0.10
South Dakota	16.2	− 5.2	Spearfish	68	22	Pine Ridge	−34	9	0.30	− 0.37	Walters Ranch	1.64	3 stations	0.00
Tennessee	39.7	− 0.2	2 stations	73	8†	Crossville	7	15	3.84	− 0.73	Liberty	5.53	Lebanon	2.06
Texas	47.7	− 0.7	Mercedes	89	8	Dalhart	− 6	10	1.12	− 1.40	Beaumont	6.02	12 stations	0.00
Utah	21.9	− 4.2	Leeds (near)	80	28	Duchesne	−39	9	0.95	− 0.14	Silver Lake	4.77	Mohrland	0.00
Virginia	35.0	− 2.7	Hopewell	78	13	Mineral	− 7	21	2.50	− 0.84	Mendota	5.46	Clarksville	1.06
Washington														
West Virginia	30.4	− 3.1	3 stations	72	9	Smithfield	−15	20	4.07	+ 0.74	Pickens	7.35	Harpers Ferry	1.17
Wisconsin	10.2	−10.3	6 stations	43	26	Winter	−45	15	0.75	− 0.56	2 stations	1.65	Prentice	0.12
Wyoming	17.2	− 3.9	Crow Hill	76	22	Riverside	−47	9	0.72	+ 0.11	Riverside	2.27	Wyncote	T.

* For explanation of the following tables and charts, see this REVIEW, January, 1919, pp. 52–53.

† Other dates also.

TABLE I.—*Climatological data for Weather Bureau stations, December, 1919.*

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.									Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation.			Wind.					Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max. + mean min. ÷ 2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.				Total.	Departure from normal.	Days with 0.01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.						
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles.								0–10	In.	In.
New England.							24.6	-4.5										76	2.18	-1.2										6.5		
Eastport	76	67	85	29.96	30.04	+0.06	20.0	-5.3	47	13	28	-16	18	12	37	19	14	76	3.02	-1.0	12	8,958	nw.	38	w.	10	7	10	14	6.3	16.9	3.8
Greenville, Me	1,070	6	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Portland, Me	103	82	117	29.97	30.10	+.07	22.8	-4.3	52	13	30	-10	18	16	32	20	14	71	1.78	-1.9	10	6,408	sw.	36	nw.	10	17	3	11	4.3	4.3	0.5
Concord	288	70	79	29.76	30.10	+.04	21.3	-5.1	57	13	30	-10	18	12	32	...	...	...	0.99	-2.4	7	3,534	nw.	28	nw.	10	10	8	13	5.8	2.9	0.3
Burlington	404	11	48	29.61	30.08	+.03	17.2	-5.3	47	13	25	-13	18	9	34	...	...	...	1.08	-0.6	8	9,113	s.	52	s.	12	7	7	17	7.0	11.1	0.3
Northfield	876	12	60	29.10	30.10	+.05	15.2	-5.3	56	13	26	-22	18	4	39	12	10	85	1.29	-1.4	11	4,975	s.	33	nw.	10	6	3	22	7.5	10.5	3.8
Boston	125	115	188	29.95	30.09	+.04	28.7	-2.9	61	13	36	-6	18	21	35	26	18	64	1.63	-1.8	11	7,430	w.	43	nw.	10	4	14	13	6.7	2.9	0.5
Nantucket	12	14	90	30.07	30.08	+.04	32.0	-4.7	56	13	38	3	18	26	27	30	26	78	3.67	0.0	17	11,509	nw.	52	ne.	25	5	7	19	7.5	4.0	T.
Block Island	26	11	46	30.06	30.10	+.03	31.5	-5.1	54	9	38	-1	18	26	29	30	27	84	3.53	-0.3	14	14,435	nw.	60	nw.	10	7	5	19	7.5	6.6	T.
Providence	160	215	251	29.92	30.10	+.04	27.9	-3.7	57	13	36	-7	18	20	33	26	21	74	2.11	-1.8	11	8,615	nw.	66	nw.	10	6	12	13	6.5	4.6	1.0
Hartford	159	122	140	29.94	30.12	+.05	26.4	-3.4	56	13	34	-6	18	19	33	23	18	73	2.06	-1.5	13	5,273	n.	40	nw.	10	8	8	15	6.4	2.8	T.
New Haven	106	74	153	30.01	30.13	+.06	27.6	-4.2	53	13	34	-4	18	21	28	25	20	75	2.78	-0.9	14	6,692	n.	34	nw.	10	9	10	12	5.9	3.7	0.7
Middle Atlantic States.							31.6	-3.7										74	2.43	-0.8										6.6		
Albany	97	102	115	30.01	30.13	+.05	23.1	-4.4	50	13	30	-9	18	16	28	21	17	78	1.23	-1.3	11	5,313	s.	38	s.	12	7	12	12	6.3	5.9	0.2
Binghamton	871	10	84	29.13	30.09	00	23.0	-4.7	52	13	31	-14	19	15	35	...	...	...	1.55	-0.9	10	4,532	nw.	27	nw.	10	5	10	16	7.2	9.8	4.3
New York	314	414	454	29.77	30.13	+.04	30.0	-4.4	60	13	37	0	18	23	36	27	21	69	2.53	-0.9	14	12,815	nw.	72	nw.	10	5	9	17	7.2	7.9	1.0
Harrisburg	374	94	104	29.75	30.18	+.06	27.5	-5.3	54	13	34	2	18	21	33	24	20	74	2.29	-0.4	12	5,225	nw.	33	nw.	10	6	7	18	6.8	8.6	0.5
Philadelphia	117	123	190	30.02	30.16	+.05	32.5	-3.2	61	13	39	4	18	26	33	29	23	68	3.33	+0.3	14	7,969	nw.	37	nw.	10	8	5	18	6.7	6.6	T.
Reading	325	81	98	29.79	30.16	.....	28.0	.....	56	13	35	0	18	21	32	25	20	74	2.49	-0.8	13	5,295	nw.	37	nw.	10	6	5	20	7.2	7.1	0.6
Scranton	805	111	119	29.24	30.14	+.04	24.9	-4.9	51	13	32	-6	18	18	28	23	19	78	2.52	-0.1	15	5,291	sw.	34	sw.	10	1	12	18	7.5	7.8	0.7
Atlantic City	52	37	48	30.07	30.13	+.03	33.7	-2.7	58	10	42	3	18	26	33	31	27	76	2.45	-1.3	16	5,618	nw.	29	nw.	10	8	7	16	6.5	3.7	0.0
Cape May	18	13	49	30.14	30.16	+.05	34.7	-3.3	60	7	42	3	18	27	30	32	28	82	2.17	-1.6	12	7,681	nw.	42	nw.	10	7	4	20	6.8	3.2	T.
Sandy Hook	22	10	57	30.11	30.13	.....	30.7	.....	57	14	36	3	18	25	33	29	25	79	2.72	.....	12	12,970	nw.	52	nw.	10	4	13	14	6.5	5.1	T.
Trenton	190	159	183	29.92	30.13	.....	28.9	.....	59	13	36	-1	18	22	35	27	22	77	2.94	-0.2	13	8,703	n.	48	nw.	10	7	7	17	6.8	4.6	0.1
Baltimore	123	100	113	30.02	30.16	+.03	33.2	-3.7	68	7	41	7	18	26	36	29	23	68	3.11	0.0	12	5,161	n.	29	nw.	14	9	9	13	5.9	5.1	0.0
Washington	112	62	85	30.03	30.16	+.03	32.6	-3.5	69	7	41	8	21	24	38	28	22	71	3.32	+0.2	10	5,280	nw.	42	nw.	10	7	10	14	6.2	4.8	T.
Lynchburg	681	153	188	29.39	30.16	+.02	36.1	-2.2	71	7	47	12	20	25	39	31	25	71	1.96	-1.3	11	5,317	w.	38	nw.	30	9	11	11	5.7	1.4	0.0
Norfolk	91	170	205	30.06	30.16	+.03	40.5	-2.5	74	9	49	20	18	32	38	37	32	75	1.71	-1.8	11	10,545	n.	46	n.	14	8	7	16	6.5	1.8	0.0
Richmond	144	11	52	30.01	30.17	+.03	35.9	-6.1	71	7	46	14	20	26	40	32	27	73	2.30	-0.7	10	4,790	ne.	34	sw.	7	9	4	18	6.1	6.0	0.0
Wytheville	2,304	49	55	27.69	30.15	.00	34.8	-0.5	67	12	44	13	15	26	41	30	25	74	2.55	-1.2	7	5,836	w.	38	w.	30	12	6	13	5.3	T.	0.0
South Atlantic States.							47.0	-0.2										75	1.86	-1.6										5.2		
Asheville	2,255	70	84	27.75	30.19	+.03	40.3	+2.5	68	7	50	14	15	30	41	34	29	71	2.09	-2.0	10	6,311	nw.	39	nw.	10	12	11	8	4.8	0.2	0.0
Charlotte	779	153	161	29.30	30.16	.00	41.6	-1.3	66	9	51	21	15	32	35	36	29	67	2.20	-1.7	9	4,466	sw.	22	s.	7	15	4	12	5.0	0.0	0.0
Hatteras	11	12	50	30.12	30.13	.00	45.8	-3.0	69	9	53	26	26	39	28	43	41	84	0.98	-4.1	9	12,614	n.	48	n.	14	7	4	20	7.1	0.0	0.0
Manteo	12	5	42	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Raleigh	376	103	110	29.75	30.17	+.02	40.2	-2.5	75	9	50	18	20	31	38	36	32	76	1.96	-1.2	8	6,456	ne.	40	nw.	14	7	8	16	6.5	0.0	0.0
Wilmington	78	81	91	30.08	30.16	+.01	47.1	-0.1	74	8	57	24	18	38	27	42	37	74	1.87	-1.2	8	6,004	n.	29	sw.	7	12	5	14	5.2	0.0	0.0
Charleston	48	11	92	30.10	30.16	+.01	51.4	+0.1	79	9	60	30	15	43	31	45	41	74	0.19	-3.0	3	8,640	n.	32	n.	10	14	9	8	4.5	0.0	0.0
Columbia, S. C.	351	41	57	29.79	30.18	+.02	46.2	-1.0	78	9	56	26	16	37	32	40	35	72	2.64	-0.3	8	5,422	n.	27	w.	28	13	6	12	4.8	0.0	0.0
Greenville, S. C.	1,013	113	122	29.02	30.14	.....	43.8	.....	69	8	53	21	15	35	34	37	32	71	6.70	.....	8	6,380	sw.	33	ne.	24	17	4	10	4.3	0.0	0.0
Augusta	180	62	77	29.97	30.16	.00	48.4	+1.4	78	9	58	25	26	38	36	43	39	77	1.91	-1.5	8	4,371	nw.	24	nw.	14	13	3	15	5.3	0.0	0.0
Savannah	65	150	194	30.09	30.16	+.01	52.6	+1.3	79	9	61	31	16	44	28	46	41	72	0.12	-3.0	4	9,192	n.	39	w.	29	12	9	10	5.0	0.0	0.0
Jacksonville	43	209	245	30.11	30.16	+.02	56.1	+0.9	80	9	65	34	16	47	36	51	48	82	4.61	+1.6	6	9,909	n.	44	n.	22	17	6	8	4.4	0.0	0.0
Florida Peninsula.							67.9	+1.5										77	1.45	-0.6										4.2		
Key West	22	10	64	30.07	30.09	+.01	72.0	+1.9	83	14	76	59	31	68	14	66	64	80	1.10	-0.7	5	8,225	ne.	25	nw.	23	18	9	4	3.5	0.0	0.0
Miami	25	71	79	30.08	30.12	.....	68.8	+0.8	80	1	76	40	24	62	28	62	59	77	1.83	-0.4	6	6,468	nw.	25	e.	12	9	15	7	5.0	0.0	0.0
Sand Key	23	39	72	30.04	30.07	-.01	71.6	.....	79	14	74	63	30	69	10	67	64	76	.....	.....		12,912	ne.	39	(*)	16	17	11	3	3.8	0.0	0.0
Tampa	35	79	92	30.10	30.14	+.02	63.0	+1.8	84	10	72	39	16	54	26	55	52	78	1.42	-0.6	7	4,741	n.	24	e.	21	14	6	11	4.4	0.0	0.0
East Gulf States.							50.2	+1.1										76	6.95	+2.4										5.3		
Atlanta	1,174	190	216	28.91	30.18	+.02	44.8	+0.2	67	6	53	18	15	37	38	40	36	79	12.94	+8.4	9	9,125	nw.	48	nw.	10	14	4	13	5.1	0.0	0.0
Macon	370	78	87	29.77	30.18	+.02	48.1	+1.3	75	9	59	24	15	38	34	41	37	74	2.76	-1.6	10	5,055	nw.	31	nw.	14	13	6	12	5.0	0.0	0.0
Thomasville	273	49	58	29.87	30.17	+.02	53.0	+0.5	78	8	63	29	16	43	34	46	44	73	2.56	-1.1	6	3,984	ne.	20	sw.	7	15	5	11	4.9	0.0	0.0
Pensacola	56	149	86	30.12	30.18	+.03	55.3	+1.4	74	8	63	30	15	48	37	50	45	74	4.15	0.0	6	10,821	ne.	46	ne.	10	15	5	11	4.8	0.0	0.0
Anniston	741	9	57	29.39	30.20	+.04	44.5	+0.3	70	6	55	17	15	34	34	...	...	...	10.69	+6.2	12	4,444	nw.	26	w.	7	10	8	13	5.7	0.0	0.0
Birmingham	700	11	48	29.42	30.20	+.04	45.8	-1.5	70	6	55	17	15	37	32	41	36	74	9.56	+5.0	9	4,977	n.	28	w.	7	10	7	14	5.6	T.	0.0
Mobile	57	125	161	30.11	30.18	+.03	55.0	+3.5	77	7	64	29	15	46	36	48	44	75	5.42	+0.8	9	8,056	n.	41	n.	10	13	8	10	4.9	0.0	0.0
Montgomery	223	100	112	29.95	30.20	+.04	50.4	+1.3	74	6	59	24	15	41	27	44	39	72	10.04	+5.5	8	5,360	n.	27	nw.	7	15	5	11	4.8	0.0	0.0
Corinth	469	6	...	...	...	...	42.4	.....	71	6	53	15	14	32	39	...	...	...	3.06	.....	8	.....	n.	...	...	...	8	8	15	...	0.0	0.0
Jackson	304	5	...	...	...	...	49.7	.....	78	9	60	22	15	40	37	...	...	...	7.20	.....	7	.....	sw.	...	...	...	10	12	9	...	T.	0.0
Meridian	375	85	93	29.78	30.19	+.03	49.1	+2.2	74	6	59	20	15	39	42	44	40	79	11.34	+6.1	6	4,441	sw.	27	nw.	9	10	9	12	5.5	T.	0.0
Vicksburg	247	65	74	29.90	30.19	+.04	49.4	0.0	74	6	58	23	14	40	40	44	40	76	6.21	+1.2	9	5,232	n.	28	nw.	9	6	9	16	6.4	T.	0.0
New Orleans	53	76	84	30.12	30.18	+.05	57.0	+2.6	81	9	65	34	15	49	33	52	49	82	0.83	-3.6	6	5,569	ne.	27	ne.	10	12	9	10	5.1	0.0	0.0
West Gulf States.							47.8	-1.2										72	1.35	-1.5										6.3		
Shreveport	249	77	93	29.93	30.21	+.08	48.8	-0.1	75	6	58	21	14	39	43	43	38	74	2.08	-2.3	7	5,285	n.	28	w.	9	8	10	13	6.0	0.0	0.0
Bentonville	1,303	11	44	28.76	30.18	+.05	35.8	-1.7	70	30	46	3	10	25	43	...	...	...	0.46	-2.3	5	4,437	n.	24	s.	12	11	9	11	5.7	0.4	0.0
Fort Smith	457	79	94	29.69	30.19	+.06	39.2	-2.5	72	30	49	12	14	30	37	35	30	74	0.15	-2.7	4	5,292	e.	29	sw.	12	11	6	14	5.6	T.	0.0
Little Rock	357	139	147	29.80	30.19	+.05	40.6	-2.9	69	6	50	14	14	31	33	37	32	75	2.34	-1.9	8	6,164	n.	36	n.	31	10	8	13	5.9	0.0	0.0
Brownsville	57	4	26	...	...	...	60.8	.....	88	9	72	32	10	49	38	...	...	...	1.08	.....	8	.....	n.	...	...	...	...	...	...	...	...	...
Corpus Christi	20	69	77	30.16	30.18	+.06	56.0	-0.6	82	8	66	27	14	46	47	51	48	82	0.20	-1.1	2	7,262	n.	37	n.	9	7	6	18	6.9	0.0	0.0
Dallas	512	109	117	29.64	30.22	.....	44.3	.....	78	6	54	15	4	34	40	...	...	...	0.48	.....	5	5,626	nw.	31	nw.	9	7	8	16	6.5	T.	0.0
Fort Worth	670	106	114	29.45	30.18	+.06	44.4	-3.1	77	6	55	15	10	34	46	40	36	77	0.44	-0.8	6	6,934	nw.	36	nw.	9	6	11	14	6.6	T.	0.0
Galveston	54	106	114	30.13	30.19	+.07	57.2	+0.9	76	8	64	30	14	50	43	54	51	84	2.02	-1.7	9	8,712	n.	40	n.	9	9	9	13	5.8	0.0	0.0
Houston	138	111	121	30.02	30.18	.....	55.4	+0.9	82	8	65	27	14	45	44	...	...	...	3.04	.....	8	6,074	nw.	31	nw.	9	6	10	15	6.5	0.0	0.0
Palestine	510	64	72	29.66	30.20	+.08	48.6	-0.8	75	30	58	17	14	39	48	43	39	78	2.16	-1.5	11	5,262	n.	24	sw.	31	7	9	15	6.3	T.	0.0
Port Arthur	34	58	66	30.12	30.16	.....	55.0	.....	80	9	64	28	14	46	45	51	48	83	1.91	.....	9	7,291	e.	33	n.	9	8	7	16	6.5	0.0	0.0
San Antonio	701	119	132	29.45	30.20	+.09	51.7	-1.4	76	8	61	25	14	42	38	46	41	75	2.05	+0.5	9	5,129	n.	34	nw.	26	8	5	18	6.6	0.0	0.0
Taylor	582	55	63	29.60	30.22	+.11	48.6	-2.0	75	6	59	19	14	38	41	...	...	...	1.60	-1.0	7	6,037	n.	31	n.	9	5	6	20	7.2	T.	0.0

* Vane down.

TABLE I.—*Climatological data for Weather Bureau stations, December, 1919*—Continued.

Districts and stations.	Elevation of instruments: Barometer above sea level.	Elevation of instruments: Thermometer above ground.	Elevation of instruments: Anemometer above ground.	Pressure: Station, reduced to mean of 24 hours.	Pressure: Sea level, reduced to mean of 24 hours.	Pressure: Departure from normal.	Temperature of the air: Mean max.+mean min.÷2.	Temperature of the air: Departure from normal.	Temperature of the air: Maximum.	Temperature of the air: Date.	Temperature of the air: Mean maximum.	Temperature of the air: Minimum.	Temperature of the air: Date.	Temperature of the air: Mean minimum.	Temperature of the air: Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation: Total.	Precipitation: Departure from normal.	Precipitation: Days with 0.01 inch or more.	Wind: Total movement.	Wind: Prevailing direction.	Wind: Maximum velocity: Miles per hour.	Wind: Maximum velocity: Direction.	Wind: Maximum velocity: Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In	In.		Miles.								0-10	In.	In.
Ohio Valley and Tennessee.							**32.3**	**− 4.3**										**77**	**3.46**	**0.0**										**6.5**		
Chattanooga	762	189	213	29.37	30.20	+ .04	42.4	− 0.2	68	9	50	17	15	34	30	38	32	70	4.88	+ 0.5	9	6,147	sw.	36	sw.	6	9	6	16	6.0	0.1	0.0
Knoxville	996	102	111	29.09	30.17	+ .01	41.0	+ 1.3	72	9	49	18	15	33	32	37	32	75	4.25	+ 0.1	8	5,222	sw.	40	sw.	6	8	6	17	6.4	T.	0.0
Memphis	399	76	97	29.79	30.23	+ .08	40.4	− 3.1	68	31	48	15	14	32	45	36	32	75	2.61	− 1.8	8	6,656	n.	34	nw.	9	13	3	15	5.6	0.0	0.0
Nashville	546	168	191	29.60	30.20	+ .05	38.8	− 1.3	66	6	48	12	14	30	40	35	30	75	3.28	− 0.5	11	6,988	sw.	40	nw.	9	9	7	15	6.2	T.	0.0
Lexington	989	193	230	29.08	30.19	+ .05	31.2	− 5.2	60	6	39	9	10	23	39	....	....	....	6.70	+ 3.4	7	9,997	sw.	36	sw.	6	9	4	18	6.6	2.3	0.0
Louisville	525	219	255	29.59	30.20	+ .06	32.3	− 5.8	61	6	40	8	10	24	40	29	25	76	5.89	+ 2.2	7	9,014	n.	42	nw.	6	12	5	14	5.5	1.2	0.0
Evansville	431	139	175	29.71	30.19	+ .06	32.2	− 4.2	59	31	40	6	10	25	33	29	26	79	1.86	− 2.0	7	7,884	sw.	33	sw.	11	9	9	13	5.7	0.6	0.0
Indianapolis	822	194	230	29.25	30.17	+ .05	26.1	− 6.5	53	12	33	0	10	19	30	24	20	79	0.85	− 2.2	5	8,781	w.	42	sw.	12	7	5	19	6.8	3.7	T.
Terre Haute	575	96	129	29.53	30.17	......	26.8	......	54	12	34	0	10	20	29	24	19	75	0.83	......	3	7,326	nw.	37	s.	12	8	6	17	6.8	1.6	0.0
Cincinnati	628	11	51	29.47	30.18	+ .06	27.4	− 7.0	57	13	36	2	20	19	37	25	22	81	2.56	− 0.4	9	6,244	sw.	26	sw.	12	10	7	14	6.1	4.4	0.0
Columbus	824	179	222	29.25	30.16	+ .04	26.0	− 6.8	58	12	34	6	10	18	34	24	20	78	2.26	− 0.5	11	8,889	nw.	40	w.	15	5	7	19	7.3	5.4	0.0
Dayton	899	181	216	29.14	30.14	......	26.7	− 6.4	53	12	35	5	10	19	33	24	21	80	1.66	− 1.0	9	7,928	sw.	38	sw.	12	9	7	15	6.5	2.3	0.0
Pittsburgh	842	353	410	29.21	30.15	+ .04	28.2	− 6.5	62	12	36	6	18	20	32	25	21	74	2.88	+ 0.2	13	8,709	nw.	53	nw.	30	5	3	23	8.0	8.6	1.0
Elkins	1,947	41	50	28.02	30.18	+ .06	29.1	− 3.4	68	9	41	−6	17	17	44	25	22	84	4.73	+ 1.3	17	4,289	w.	31	w.	30	4	9	18	7.3	20.5	1.8
Parkersburg	638	77	82	29.50	30.18	+ .04	30.4	− 4.8	65	13	40	2	20	21	35	26	23	77	4.07	+ 1.3	11	4,609	sw.	32	w.	10	6	7	18	7.1	7.5	T.
Lower Lake Region.							**23.2**	**− 6.0**										**75**	**1.44**	**− 1.4**										**7.3**		
Buffalo	767	247	280	29.23	30.09	+ .03	23.3	− 6.8	55	12	30	− 3	17	16	27	21	18	79	1.96	− 1.4	17	13,871	w.	58	s. w.	26	3	5	23	8.4	15.5	6.5
Canton	448	10	61	29.55	30.05	......	17.2	− 5.5	53	13	26	−19	18	8	32	....	....	....	1.12	− 2.5	15	8,081	sw.	42	n. w.	10	8	6	17	6.9	8.7	1.8
Oswego	335	76	91	......	30.09	+ .03	22.1	− 7.1	51	13	30	−13	18	15	26	....	....	....	2.36	− 1.2	20	8,804	s.	41	n. e.	24	1	6	24	....	47.2	10.0
Rochester	523	97	102	29.51	30.10	+ .04	23.4	− 5.5	57	13	31	− 7	18	16	28	21	15	70	1.68	− 1.2	15	7,205	sw.	35	w.	10	4	6	21	7.6	19.1	6.0
Syracuse	597	97	113	29.42	30.10	+ .03	22.6	− 5.7	55	13	30	−13	18	15	39	....	....	....	2.24	− 0.4	17	8,835	s.	47	w.	10	3	12	16	7.2	20.3	5.8
Erie	714	130	166	29.30	30.10	+ .03	25.4	− 6.3	57	12	32	0	18	19	28	23	19	75	1.80	− 1.3	16	11,941	sw.	50	se.	11	4	9	18	7.6	25.3	4.0
Cleveland	762	190	201	29.28	30.14	+ .05	25.7	− 5.4	56	12	32	5	18	20	31	23	18	74	1.32	− 1.3	15	10,578	sw.	49	nw.	30	4	7	20	7.9	7.6	0.5
Sandusky	629	62	103	29.44	30.15	+ .06	25.2	− 5.9	54	12	32	7	18	19	33	....	....	....	0.66	− 1.7	11	9,970	sw.	46	nw.	30	5	9	17	7.1	4.3	T.
Toledo	628	208	243	29.44	30.15	+ .07	23.8	− 6.7	50	12	30	5	17	17	28	21	17	74	0.33	− 2.0	7	10,458	sw.	39	w.	9	6	10	15	6.8	4.2	0.1
Fort Wayne	856	113	124	29.20	30.16	......	22.9	− 4.4	50	12	30	− 4	10	16	34	20	15	74	0.48	......	5	7,061	w.	32	sw.	12	7	6	18	6.7	2.6	0.0
Detroit	730	218	245	29.30	30.13	+ .06	23.2	− 6.3	48	13	29	3	17	17	28	21	17	77	0.97	− 1.4	11	9,235	w.	38	sw.	13	6	7	18	6.7	9.3	1.1
Upper Lake Region.							**16.2**	**− 8.3**										**82**	**1.31**	**− 0.8**										**75**		
Alpena	609	13	92	29.38	30.07	+ .05	18.2	− 6.6	38	12	25	− 4	17	12	26	17	14	82	0.72	− 1.5	9	8,518	sw.	38	se.	11	3	10	18	7.5	7.9	4.2
Escanaba	612	54	60	29.40	30.10	+ .07	13.0	− 8.6	38	26	20	−14	15	6	26	12	9	86	0.43	− 1.3	5	6,895	nw.	36	n.	23	10	2	19	6.2	5.5	4.0
Grand Haven	632	54	89	29.41	30.13	+ .08	21.5	− 8.6	41	12	27	1	19	16	33	21	18	82	2.31	− 0.2	15	10,132	w.	47	w.	9	2	3	26	8.7	29.9	3.9
Grand Rapids	707	70	87	29.33	30.14	+ .09	21.4	− 7.4	42	12	27	3	17	16	27	20	16	79	1.19	− 1.4	11	4,842	nw.	24	w.	12	2	4	25	8.5	15.0	3.0
Houghton	684	62	99	29.32	30.08	+ .06	12.6	− 8.3	36	26	19	−10	18	6	31	....	....	....	5.67	+ 3.2	21	7,787	w.	39	w.	26	1	1	29	9.4	57.6	20.3
Lansing	878	11	62	29.14	30.12	......	19.4	− 7.4	43	12	27	− 5	17	12	32	18	15	85	0.86	− 1.2	13	5,240	nw.	24	nw.	29	3	8	20	7.9	10.2	0.8
Ludington	637	60	66	29.38	30.11	......	21.0	......	39	12	26	0	19	16	29	20	17	83	1.29	......	15	9,874	w.	37	sw.	25	0	5	26	8.9	21.5	5.5
Marquette	734	77	111	29.25	30.10	+ .08	13.7	− 9.2	37	26	20	− 9	15	7	22	11	8	81	1.89	− 0.6	14	7,726	sw.	29	sw.	10	6	6	19	7.2	21.5	18.9
Port Huron	638	70	120	29.39	30.11	+ .05	21.6	− 5.7	45	13	27	1	16	16	28	20	17	85	0.62	− 1.6	11	9,037	nw.	37	nw.	30	4	10	17	7.2	11.3	3.0
Saginaw	641	69	77	29.39	30.11	......	19.4	......	42	12	26	− 3	17	13	29	18	15	82	0.49	− 1.4	9	6,756	sw.	27	sw.	26	7	6	18	7.0	7.0	0.8
Sault Ste. Marie	614	11	52	29.33	30.06	+ .06	13.2	− 7.3	34	23	20	−22	17	6	30	12	9	82	1.86	− 0.5	18	5,595	sw.	42	nw.	26	3	7	21	7.8	21.0	10.0
Chicago	823	140	310	29.24	30.17	+ .09	21.4	− 7.8	44	12	28	− 8	10	15	30	20	16	76	0.70	− 1.4	8	8,837	w.	33	w.	12	6	6	19	6.9	7.8	T.
Green Bay	617	109	144	29.42	30.13	+ .09	12.0	− 9.3	40	26	19	−15	10	5	24	11	7	77	0.36	− 1.4	7	8,678	sw.	38	nw.	29	6	8	17	7.2	6.3	2.9
Milwaukee	681	125	139	29.37	30.14	+ .08	16.4	− 9.6	40	26	23	− 9	10	10	26	16	13	84	0.92	− 1.0	8	7,794	w.	28	sw.	4	7	5	19	6.8	15.7	3.2
Duluth	1,133	11	47	28.82	30.12	+ .07	5.6	−12.1	38	25	13	−25	15	−2	33	4	2	90	0.30	− 0.9	8	9,990	sw.	51	nw.	29	12	7	12	5.1	3.0	3.8
North Dakota.							**8.4**	**− 3.4**										**86**	**0.42**	**− 0.2**										**5.0**		
Moorhead	940	8	57	29.12	30.20	+ .12	7.2	− 3.5	41	25	15	−22	10	−1	31	7	4	86	0.78	0.0	11	6,222	nw.	31	nw.	7	16	5	10	5.0	8.0	7.0
Bismarck	1,674	8	57	28.32	30.22	+ .14	11.5	− 3.4	46	22	21	−26	10	2	35	9	6	82	0.23	− 0.4	3	6,386	nw.	38	nw.	25	15	10	6	4.2	3.9	T.
Devils Lake	1,482	11	44	28.98	30.14	+ .08	5.0	− 3.0	40	25	14	−27	8	−3	36	4	2	90	0.42	0.0	6	7,956	nw.	40	nw.	25	15	4	12	5.2	7.6	3.2
Ellendale	1,457	10	56	28.53	30.18	......	10.4	......	46	25	18	−21	10	2	31	9	7	88	0.38	......	7	9,819	nw.	50	nw.	25	7	12	12	5.8	5.0	0.4
Grand Forks	835	12	89	......	......	......	......	......	....	....	....	....	....	....	....	....	....	....	......	......	....	......	......	....	......	....	....	....	....	....	....	....
Williston	1,878	41	48	28.07	30.17	+ .11	9.7	− 3.9	42	25	18	−27	10	2	32	8	5	85	0.25	− 0.4	4	5,780	sw.	45	nw.	25	10	13	8	4.7	2.1	T.
Upper Mississippi Valley.							**19.1**	**− 8.1**										**82**	**0.72**	**− 1.1**										**6.9**		
Minneapolis	918	102	208	29.12	30.15	......	10.9	......	40	29	18	−14	15	4	31	....	....	....	0.68	− 0.3	5	7,809	nw.	32	w.	25	6	7	18	7.1	8.0	7.7
St. Paul	837	236	261	29.21	30.17	+ .09	10.2	− 9.1	40	29	17	−17	10	3	32	....	....	....	0.66	− 0.4	8	8,206	sw.	39	w.	25	5	8	18	7.0	8.7	7.0
La Crosse	714	11	48	29.36	30.19	+ .11	11.6	−11.2	43	29	19	−18	10	4	30	....	....	....	0.70	− 0.6	7	3,965	nw.	20	nw.	29	4	9	18	7.5	10.6	6.5
Madison	974	70	78	29.07	30.19	+ .11	12.6	−10.1	39	29	19	−16	10	6	28	12	8	82	0.93	− 0.8	9	6,714	w.	31	n.	23	5	2	24	8.0	10.9	6.2
Wausau	1,247	4	....	28.71	30.12	......	8.6	......	36	26	16	−20	10	1	28	....	....	....	0.56	......	7	......	......	....	......	....	7	6	18	....	8.0	8.3
Charles City	1,015	10	49	29.06	30.20	+ .10	10.2	− 8.8	40	29	18	−22	10	2	31	10	8	91	0.47	− 0.8	7	4,849	nw.	23	n.	31	6	8	17	7.0	6.8	2.2
Davenport	606	71	79	29.50	30.21	+ .11	17.5	− 9.7	42	30	24	−14	10	11	37	17	15	87	0.58	− 1.1	8	5,567	sw.	23	nw.	12	5	8	18	6.9	7.0	T.
Des Moines	861	84	97	29.25	30.21	+ .10	16.6	− 9.1	46	30	24	−19	10	10	27	16	12	82	0.93	− 0.4	6	5,343	sw.	25	sw.	25	10	5	16	6.6	12.6	3.0
Dubuque	698	81	96	29.42	30.22	+ .12	14.4	−10.1	41	29	21	−18	10	7	30	14	11	84	0.63	− 1.1	7	4,705	nw.	23	nw.	29	5	9	17	7.3	12.6	4.4
Keokuk	614	64	78	29.51	30.22	+ .10	22.3	− 2.2	50	30	29	− 8	10	15	40	20	15	74	0.18	− 1.7	5	5,853	sw.	28	w.	12	6	7	18	6.8	0.5	0.0
Cairo	356	87	93	29.79	30.19	+ .04	34.0	− 4.5	63	31	42	8	10	26	31	31	28	81	2.16	− 1.2	9	7,297	n.	35	nw.	31	11	4	16	6.1	T.	0.0
Peoria	609	11	45	29.50	30.20	+ .09	20.6	− 7.5	45	12	28	− 9	10	13	39	19	17	89	0.30	− 2.1	5	5,422	w.	22	nw.	31	7	7	17	6.7	1.2	0.0
Springfield, Ill	644	10	91	29.47	30.18	+ .06	24.2	− 7.1	49	12	31	− 4	10	17	36	22	19	81	0.30	− 2.1	3	6,422	nw.	28	se.	11	8	7	16	6.5	0.8	0.0
Hannibal	534	74	109	29.60	30.20	+ .08	25.0	−10.5	54	30	32	− 6	10	17	41	....	....	....	0.36	− 1.3	7	6,647	sw.	25	sw.	14	6	11	14	6.6	0.9	0.0
St. Louis	567	265	303	29.55	30.18	+ .05	29.6	− 5.9	56	12	38	1	10	22	36	26	21	73	1.22	− 1.0	4	9,148	nw.	51	sw.	12	10	5	16	6.4	0.3	0.0
Missouri Valley.							**22.2**	**− 4.6**										**83**	**0.34**	**− 0.7**										**5.5**		
Columbia, Mo	781	11	84	29.33	30.20	+ .08	27.0	− 5.9	59	30	35	− 4	10	19	45	....	....	....	0.55	− 1.5	5	6,193	sw.	30	nw.	12	8	7	16	6.3	0.8	0.0
Kansas City	963	161	181	29.13	30.21	+ .09	25.9	− 5.6	61	30	33	− 5	10	19	34	23	19	78	0.16	− 1.2	5	8,934	n.	37	n.	31	13	0	18	6.3	0.5	0.0
St. Joseph	967	11	49	29.12	30.21	......	22.8	......	59	30	30	−11	10	16	34	21	18	82	0.22	......	4	5,998	sw.	29	nw.	31	12	2	17	6.2	1.2	T.
Springfield, Mo	1,324	98	104	28.74	30.19	+ .06	32.6	− 2.9	66	30	42	0	10	23	47	28	25	82	0.44	− 2.2	6	8,065	nw.	31	se.	11	15	5	11	4.8	0.3	0.0
Iola	984	11	50	29.10	30.20	+ .08	28.6	− 3.9	65	30	37	− 3	10	20	35	....	....	....	0.19	− 0.7	3	5,425	sw.	24	n.	31	8	6	17	6.5	0.3	0.0
Topeka	987	92	107	......	......	......	25.3	− 5.8	67	30	33	− 9	10	18	36	....	....	....	0.07	− 0.8	3	7,259	n.	32	n.	31	11	3	17	6.1	0.7	0.0
Drexel	1,299	10	53	28.71	30.17	......	17.4	......	48	30	26	−23	10	9	33	16	14	91	0.75	......	5	7,731	sw.	30	sw.	25	10	10	11	5.4	8.6	T.
Lincoln	1,189	11	84	28.88	30.22	+ .10	20.6	− 6.3	54	30	29	−20	10	12	35	18	16	87	0.73	+ 0.1	3	7,110	s.	32	n.	31	11	5	15	5.6	9.1	T.
Omaha	1,105	115	122	28.97	30.22	+ .11	19.4	− 7.7	50	30	26	−16	10	12	28	18	15	83	0.69	− 0.2	5	6,364	nw.	36	n	31	11	7	13	5.5	8.1	0.2
Valentine	2,598	47	54	27.37	30.22	+ .12	20.0	− 4.5	53	30	30	−22	9	10	45	16	13	82	0.22	− 0.4	6	6,620	w.	42	nw.	18	17	8	6	3.6	3.9	0.2
Sioux City	1,135	94	164	28.93	30.22	+ .10	17.2	− 5.4	46	29	24	−16	10	10	27	15	12	84	0.40	− 0.3	5	7,590	nw.	36	nw.	12	9	10	12	5.5	4.9	1.2
Huron	1,306	59	74	28.75	30.22	+ .12	14.4	− 1.3	46	25	22	−15	10	7	29	12	9	80	0.29	− 0.3	7	7,580	nw.	31	n.	31	10	8	13	5.5	2.5	0.4
Pierre	1,572	70	75	28.46	30.21	+ .11	18.6	− 1.5	54	30	27	−15	2	10	31	16	12	77	0.12	− 0.4	3	5,118	nw.	32	nw.	13	12	8	11	4.8	1.9	T.
Yankton	1,233	49	57	28.80	30.20	+ .09	17.4	− 4.8	49	29	26	−16	10	9	30	....	....	....	0.22	− 0.5	7	5,468	w.	26	nw.	12	11	7	13	5.5	2.7	0.7

TABLE I.—*Climatological data for Weather Bureau stations, December, 1919*—**Continued.**

Districts and stations.	Elevation of instruments: Barometer above sea level.	Elevation: Thermometer above ground.	Elevation: Anemometer above ground.	Pressure: Station, reduced to mean of 24 hours.	Pressure: Sea level, reduced to mean of 24 hours.	Pressure: Departure from normal.	Temperature: Mean max.+mean min.÷2.	Temperature: Departure from normal.	Temperature: Maximum.	Temperature: Date.	Temperature: Mean maximum.	Temperature: Minimum.	Temperature: Date.	Temperature: Mean minimum.	Temperature: Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation: Total.	Precipitation: Departure from normal.	Precipitation: Days with 0.01 inch or more.	Wind: Total movement.	Wind: Prevailing direction.	Wind: Maximum velocity: Miles per hour.	Wind: Maximum velocity: Direction.	Wind: Maximum velocity: Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles.								0–10	In.	In.
Northern Slope.							**18.4**	**-5.2**										**74**	**0.78**	**-0.1**										**4.6**		
Billings	3,140	5					16.1		51	28	26	-36	9	6	45				0.77		7		sw.				17	10	4		14.5	1.0
Havre	2,505	11	44	27.42	30.19	+.14	16.9	-4.3	58	24	26	-31	9	7	45	14	11	80	0.20	-0.4	3	7,370	sw.	36	sw.	16	10	7	14	5.6	2.0	0.6
Helena	4,110	87	112	25.88	30.29	+.16	16.1	-8.7	57	24	25	-28	9	8	41	12	8	76	0.98	+0.2	8	4,572	sw.	42	sw.	17	4	12	15	6.4	21.6	7.6
Kalispell	2,962	11	34		30.26	+.19	17.6	-6.3	53	24	25	-24	9	10	27				0.91	-0.9	10	3,034	nw.	25	nw.	30	7	5	19	3.8	8.2	0.1
Miles City	2,371	26	48	27.58	30.27	+.17	15.6	-5.4	47	28	25	-30	9	6	32	13	11	87	0.55	-0.1	7	3,807	se.	28	nw.	18	16	9	6	3.8	11.1	0.3
Rapid City	3,259	50	58	26.66	30.24	+.15	22.7	-2.3	58	30	34	-23	9	12	46	17	9	61	0.30	-0.2	5	6,285	w.	37	n.	18	17	8	6	4.0	4.9	0.6
Cheyenne	6,088	84	101	23.98	30.15	+.06	28.0	-1.0	59	21	39	-28	9	17	47	21	12	57	1.10	+0.8	6	12,145	w.	60	w.	14	20	7	4	3.0	11.9	0.0
Lander	5,372	60	68	24.68	30.31	+.16	14.2	-5.0	54	30	27	-36	9	2	61	11	5	69	0.57	-0.1	5	3,448	sw.	56	sw.	10	15	10	6	4.3	5.7	0.5
Sheridan	3,790	10	47	26.16	30.28		13.7		52	30	26	-41	9	1	37	10	7	80	0.35		8	3,968	s.	32	nw.	30	15	8	8	4.6	5.8	0.7
Yellowstone Park	6,200	11	48	23.90	30.30	+.14	15.4	-6.2	44	21	26	-31	9	5	58	13	9	75	2.13	+0.3	12	6,710	s.	40	s.	10	5	10	16	6.7	27.7	14.5
North Platte	2,821	11	51	27.19	30.28	+.18	19.4	-7.2	55	30	30	-25	9	9	36	15	12	82	0.32	-0.2	3	4,827	w.	27	nw.	12	19	5	7	3.8	3.2	T.
Middle Slope.							**30.0**	**-3.2**										**74**	**0.27**	**-0.5**										**3.8**		
Denver	5,292	106	113	24.74	30.16	+.08	33.0	-0.8	68	29	45	-20	9	21	52	24	13	52	0.44	-0.2	5	6,046	s.	38	n.	12	17	8	6	3.5	6.1	0.0
Pueblo	4,685	80	86	25.34	30.17	+.09	30.9	-0.8	69	29	46	-22	9	16	58	24	16	64	0.59	+0.1	5	4,033	nw.	46	w.	12	17	9	5	3.5	6.1	0.0
Concordia	1,392	50	58	28.69	30.23	+.12	24.4	-5.1	62	30	33	-14	10	16	33	22	19	85	0.24	-0.2	4	5,832	w.	28	nw.	12	11	6	14	5.7	2.3	T.
Dodge City	2,509	11	51	27.53	30.24	+.14	29.6	-2.0	69	30	43	-10	9	16	44	23	20	81	0.08	-0.5	3	6,793	nw.	36	s.	10	17	9	5	3.6	0.8	0.0
Wichita	1,358	139	158	28.72	30.22	+.11	28.2	-6.0	62	29	36	-4	9	20	37	26	23	83	0.14	-0.6	3	8,988	s.	36	s.	11	12	6	13	5.5	0.2	0.0
Altus	1,410	5																														
Muskogee	652	4																														
Oklahoma	1,214	10	47	28.89	30.23	+.12	33.8	-4.8	72	30	44	3	10	24	42	29	25	80	0.12	-1.6	4	10,569	n.	42	s.	11	9	9	13	5.9	0.4	0.0
Southern Slope.							**42.4**	**-1.3**										**66**	**0.32**	**-0.5**										**4.7**		
Abilene	1,738	10	52	28.34	30.20	+.09	43.2	-1.8	73	30	56	10	14	31	50	36	29	65	0.25	-0.9	3	6,638	s.	35	sw.	6	9	9	13	5.6	T.	0.0
Amarillo	3,676	10	49	26.35	30.18	+.09	37.0	+0.6	73	11	52	-2	9	22	66	30	24	71	0.50	-0.3	6	7,702	sw.	42	s.	10	19	7	5	3.5	1.2	0.0
Del Rio	944	64	71	29.16	30.17	+.07	49.6	-2.8	75	7	59	25	14	40	38				0.28	-0.6	8	4,849	se.	42	nw.	26	9	6	16	6.3	0.0	0.0
Roswell	3,566	75	85	26.46	30.15	+.08	40.0	-1.2	71	12	55	12	13	25	47	33	25	61	0.24	-0.3	3	4,472	s.	34	w.	8	21	1	9	3.2	0.0	0.0
Southern Plateau.							**40.9**	**+1.6**										**57**	**0.31**	**-0.4**										**2.9**		
El Paso	3,762	110	133	26.29	30.12	+.09	47.2	+2.4	74	5	59	26	29	35	37	38	28	54	0.12	-0.4	3	6,930	nw.	48	w.	8	21	7	3	2.7	0.0	0.0
Santa Fe	7,013	57	66	23.27	30.15	+.09	34.2	+3.9	54	4	44	7	14	25	28	26	18	56	0.33	-0.4	4	5,549	n.	32	sw.	8	18	6	7	3.7	0.2	0.0
Flagstaff	6,908	8	57	23.40	30.14	+.08	29.6	+1.2	55	22	43	-9	14	16	40	23			0.73		5			43	ne.	28	19	10	2		7.5	0.5
Phoenix	1,108	76	81	28.91	30.08	+.04	54.2	+2.3	76	25	69	32	10	40	40	44	36	62	0.13	-0.5	2	3,052	e.	20	w.	5	22	5	4	2.4	0.0	0.0
Yuma	141	9	54																													
Independence	3,957	11	42	26.07	30.18	+.06	39.5	-3.1	62	28	51	18	9	28	30	31	23	57	0.67	-0.1	5	3,496	nw.	40	w.	12	20	7	4	2.9	1.6	0.0
Needles	488	4																														
Middle Plateau.							**25.0**	**-6.3**										**75**	**1.13**	**+0.2**										**4.3**		
Reno	4,532	74	81	25.54	30.22	+.07	30.4	-3.3	65	24	41	-1	9	20	43	27	23	76	3.00	+1.3	8	3,659	w.	44	sw.	11	15	6	10	4.6	33.8	0.0
Tonopah	6,090	12	20	24.12	30.19		32.4		54	29	40	4	9	25	22	27	20	62	0.33	-0.5	3	6,770	se.	34	w.	11	13	14	4	3.9	2.2	0.0
Winnemucca	4,344	18	56	25.72	30.24	+.06	28.2	-2.5	54	30	39	-10	9	17	43	24	20	74	0.94	0.0	5	5,199	ne.	42	sw.	11	14	6	11	4.7	11.7	0.0
Modena	5,479	10	43	24.70	30.23	+.11	26.1	-5.6	51	25	38	-8	9	14	37	22	17	72	0.40	-0.2	4	6,397	w.	46	sw.	11	18	5	8	3.7	0.5	0.0
Salt Lake City	4,360	163	203	25.76	30.28	+.13	24.6	-7.5	52	4	32	0	13	17	30	22	19	77	1.38	0.0	6	4,522	se.	48	n.	11	11	6	14	5.4	15.2	3.0
Grand Junction	4,602	60	68	25.56	30.32	+.22	15.6	-12.6	48	12	29	-20	9	2	36	13	11	88	0.75	+0.3	4	2,411	nw.	28	nw.	12	19	4	8	3.5	11.5	2.8
Northern Plateau.							**21.8**	**-10.2**										**82**	**1.54**	**-0.2**										**6.9**		
Baker	3,471	48	53	26.56	30.30	+.14	19.2	-8.2	46	24	28	-24	13	10	36	17	14	82	1.14	-0.4	9	4,863	se.	33	s.	10	4	8	19	6.9	7.8	0.0
Boise	2,739	78	86	27.35	30.34	+.14	23.6	-8.6	58	24	31	-7	13	16	36	22	19	81	1.20	-0.5	7	2,918	nw.	29	se.	9	8	10	13	5.9	12.1	T.
Lewiston	757	40	48	29.43	30.29	+.16	21.9	-15.6	56	24	29	-23	13	15	26				2.14	+0.6	14	2,815	e.	24	ne.	16	6	7	18	7.2	20.6	T.
Pocatello	4,477	60	68	25.58	30.30	+.11	21.0	-7.4	46	24	31	-13	14	11	33	19	15	79	1.48	+0.6	10	7,014	se.	52	sw	11	11	5	15	6.0	20.4	0.5
Spokane	1,929	101	110	28.13	30.27	+ 19	22.6	-8.2	55	24	30	-15	12	15	25	21	18	79	1.36	-1.3	12	3,342	sw.	29	s.	24	2	6	23	7.0	9.0	2.8
Walla Walla	991	57	65	29.15	30.28	+.16	22.6	-13.4	64	24	30	-14	13	16	29	21	19	87	1.92	-0.2	13	2,563	s.	24	s.	24	5	9	17	7.3	13.1	T.
North Pacific Coast Region.							**38.5**	**-3.6**										**81**	**5.32**	**-2.4**										**6.7**		
North Head	211	11	56	29.84	30.07	+.04	40.8	-3.5	58	28	45	18	11	36	17	38	35	79	5.67	-1.8	19	13,162	e.	70	s.	22	10	6	15	6.2	6.5	0.0
North Yakima	1,071	4																														
Port Angeles	29	8	48	30.12	30.15		36.6		52	20	42	13	12	31	20				2.69	-2.5	15	4,222	s.	32	ne.	9	5	4	22	7.7	0.1	0.0
Seattle	125	215	250	30.01	30.15	+.14	38.6	-2.6	60	20	44	12	12	34	18	36	32	78	4.10	-1.9	13	6,706	se.	41	s.	23	10	3	18	6.4	1.0	0.0
Tacoma	213	113	120	29.90	30.14	+.13	37.4	-2.9	62	20	43	7	12	31	21	36	33	82	4.22	-3.1	15	4,067	sw.	29	sw.	24	7	4	20	7.4	2.2	0.0
Tatoosh Island	86	7	57	29.96	30.06	+.10	41.1	-2.8	55	21	44	23	11	39	10	39	37	86	11.28	-3.3	14	18,662	e.	70	ne.	9	10	5	16	6.4	T.	0.0
Medford	1,425	4																														
Portland, Oreg.	153	68	106	29.98	30.14	+.07	33.6	-7.7	61	23	38	3	13	29	16	32	28	79	4.78	-2.6	16	4,175	e.	31	e.	10	9	9	13	5.9	17.5	0.0
Roseburg	510	9	57	29.56	30.12	+.01	39.6	-2.3	64	23	46	11	12	34	20	38	35	84	4.51	-1.4	16	1,921	nw.	18	w.	10	1	17	13	6.6	4.0	0.0
Middle Pacific Coast Region.							**46.6**	**-2.0**										**78**	**3.24**	**-1.2**										**5.9**		
Eureka	62	73	89	30.04	30.11	-.01	48.1	-0.1	66	23	55	26	13	41	21	45	42	81	4.33	-2.9	14	5,277	se.	42	sw.	10	9	5	17	6.4	0.0	0.0
Mount Tamalpais	2,375	11	18	27.61	30.12	.00	44.6	-3.0	71	28	50	28	12	40	23	40	33	71	4.45	+0.6	13	14,990	ne.	66	se.	4	13	5	13	5.1	0.0	0.0
Point Reyes Light	490	7	18	29.56	30.08		50.1	-0.5	70	27	54	37	13	46	18				3.85		14	13,099	se.	85	s.	4	10	5	16	6.2	0.0	0.0
Red Bluff	332	50	56	29.79	30.16	+.02	43.3	-3.1	65	27	51	24	14	36	29	40	36	78	2.75	-1.7	12	3,352	nw.	31	se.	10	9	7	15	6.1	0.0	0.0
Sacramento	69	106	117	30.08	30.16	+.02	44.1	-2.2	64	23	50	27	13	38	21	43	41	87	2.22	-1.3	10	4,906	se.	42	se.	10	7	9	15	6.6	0.0	0.0
San Francisco	155	208	243	29.95	30.12	.00	48.8	-2.1	62	27	54	37	13	44	17	45	41	75	3.21	-1.0	10	6,060	se.	36	se.	4	12	4	15	5.5	0.0	0.0
San Jose	141	12	110	29.99	30.14		47.2	-2.7	67	22	57	25	14	38	33				2.48	-0.6	9	4,281	se.	36	se.	10	11	7	13	5.1	0.0	0.0
South Pacific Coast Region.							**53.9**	**+1.0**										**67**	**1.97**	**-0.2**										**3.8**		
Fresno	327	89	98	29.80	30.17	+.04	47.1	+0.3	70	22	56	28	13	38	26	43	38	75	0.89	-0.6	7	3,877	nw.	25	nw.	11	14	7	10	4.6	0.0	0.0
Los Angeles	338	159	191	29.74	30.10	+.03	58.9	+2.4	87	28	68	43	31	49	37	49	41	59	1.99	-0.9	6	4,023	ne.	22	e.	4	18	10	3	2.9	0.0	0.0
San Diego	87	62	70	29.99	30.09	+.02	56.6	+0.9	84	28	66	42	13	48	34	49	43	67	0.48	-1.3	7	3,611	nw.	29	se.	4	18	6	7	3.5	0.0	0.0
San Luis Obispo	201	32	40	29.91	30.13	+.02	53.1	+0.3	83	28	66	29	9	40	43	45	38	66	4.52	+2.2	7	2,814	n.	22	se.	4	16	8	7	4.1	0.0	0.0
West Indies.																																
San Juan, P. R.	82	8	54	29.92	30.01		76.3		86	23	82	68	30	71	16				5.16	-1.0	22	8,479	e.	44	e.	13	9	16	6	4.9	0.0	0.0
Panama Canal.																																
Balboa Heights	118	7	97	29.73	29.86	+.02	79.8	-0.1	92	8	88	68	13	72	19	73	72	81	1.81	-2.4	12	5,622	n.	25	nw.	17	2	27	2	5.5	0.0	0.0
Colon	36	30	97	29.83	29.86	+.01	80.4	+0.8	87	10	85	71	13	76	15	75	74	79	7.37	-4.2	23	9,778	ne.	30	ne.	30	6	20	5	5.8	0.0	0.0

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during December, 1919, at all stations furnished with self-registering gages.*

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.													
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Abilene, Tex.	18			0.16														0.05			
Albany, N. Y.	9			0.43														0.09			
Alpena, Mich.	29			0.17														(*)			
Amarillo, Tex.	18-19			0.41														(*)			
Anniston, Ala.	7-8	2:31 p.m.	9:50 a.m.	2.66	2:44 p.m.	3:34 p.m.	0.03	0.09	0.14	0.30	0.50	0.60	0.69	0.81	0.92	1.06	1.20				
	8-9	11:31 a.m.	9:30 a.m.	3.92	1:08 a.m.	1:45 a.m.	1.62	0.07	0.15	0.29	0.57	0.69	0.81	1.08	1.15						
					2:56 a.m.	3:15 a.m.	3.00	0.14	0.48	0.61	0.73										
Asheville, N. C.	9			1.32														0.40			
Atlanta, Ga.	7-8	2:20 p.m.	9:22 a.m.	3.81	4:54 p.m.	5:24 p.m.	0.35	0.23	0.31	0.34	0.35	0.42	0.64								
					6:11 a.m.	6:55 a.m.	2.19	0.16	0.28	0.32	0.36	0.41	0.52	0.56	0.60	0.65					
	8-9	1:40 p.m.	8:40 p.m.	6.65	3:15 p.m.[1]	4:49 p.m.[1]	3.87	0.06	0.10	0.17	0.20	0.25	0.30	0.35	0.40	0.45	0.56	0.87	1.29	1.66	
Atlantic City, N. J.	10			0.30														0.19			
Augusta, Ga.	7			0.70														0.45			
Baker, Oreg.	9			0.33														(*)			
Baltimore, Md.	10			1.01														0.38			
Bentonville, Ark.	4			0.23														0.09			
Binghamton, N. Y.	13			0.35														0.12			
Birmingham, Ala.	7	D. N. a.m.	D. N. a.m.	2.63	12:22 a.m.	1:02 a.m.	0.05	0.43	0.57	0.66	0.74	0.78	0.89	0.99	1.05						
		12:12 p.m.	8:30 p.m.	1.44	1:09 p.m.	1:33 p.m.	0.01	0.17	0.33	0.47	0.60	0.72									
	8-9	12:51 p.m.	10:37 a.m.	3.70	9:20 p.m.	10:20 p.m.	1.86	0.13	0.24	0.32	0.34	0.38	0.43	0.49	0.56	0.60	0.70	1.13			
Bismarck, N. Dak.	11-12			0.19														(*)			
Block Island, R. I.	10			0.90														0.25			
Boise, Idaho.	5			0.64														(*)			
Boston, Mass.	9			0.57														0.15			
Buffalo, N. Y.	6-7			0.50														(*)			
Burlington, Vt.	6-7			0.31														(*)			
Cairo, Ill.	12			0.74														0.24			
Canton, N. Y.	9-10			0.32														(*)			
Charles City, Iowa.	8-9			0.26														(*)			
Charleston, S. C.	12			0.15														0.08			
Charlotte, N. C.	14			0.52														0.34			
Chattanooga, Tenn.	7			0.81														0.61			
Cheyenne, Wyo.	7-8			0.51														(*)			
Chicago, Ill.	6			0.35														(*)			
Cincinnati, Ohio.	12			0.50														0.23			
Cleveland, Ohio.	13			0.22														(*)			
Columbia, Mo.	5.6			0.42														(*)			
Columbia, S. C.	8			1.52														0.44			
Columbus, Ohio.	6			0.80														0.19			
Concord, N. H.	9			0.49														(*)			
Concordia, Kans.	8-9			0.22														(*)			
Corpus Christi, Tex.	18			0.19														0.08			
Dallas, Tex.	18			0.35														0.11			
Davenport, Iowa.	5			0.21														(*)			
Dayton, Ohio.	12-13			0.45														0.23			
Del Rio, Tex.	18			0.11														0.04			
Denver, Colo.	7-8			0.16														(*)			
Des Moines, Iowa.	5-6			0.50														(*)			
Detroit, Mich.	6-7			0.34														(*)			
Devils Lake, N. Dak.	17-18			0.18														(*)			
Dodge City, Kans.	8			0.05														(*)			
Drexel, Nebr.	8-9			0.45														(*)			
Dubuque, Iowa.	8-9			0.16														(*)			
Duluth, Minn.	29			0.12														(*)			
Eastport, Me.	7			0.65														0.20			
Elkins, W. Va.	6			1.20														0.43			
Ellendale, N. Dak.	11-12			0.14														(*)			
El Paso, Tex.	17			0.06														0.03			
Erie, Pa.	14-15			0.40														(*)			
Escanaba, Mich.	8-9			0.20														(*)			
Eureka, Calif.	18			0.81														0.29			
Evansville, Ind.	6			1.11														0.25			
Flagstaff, Ariz.	8			0.34														(*)			
Fort Smith, Ark.	4			0.09														0.03			
Fort Wayne, Ind.	6-7			0.38														(*)			
Fort Worth, Tex.	18			0.31														0.31			
Fresno, Calif.	11			0.25														0.18			
Galveston, Tex.	19			0.59														0.50			
Grand Haven, Mich.	6			0.75														(*)			
Grand Junction, Colo.	8			0.46														(*)			
Grand Rapids, Mich.	6			0.52														(*)			
Green Bay, Wis.	9			0.15														(*)			
Greenville, S. C.	9			3.39														0.54			
Hannibal, Mo.	5-6			0.24														(*)			
Harrisburg, Pa.	13-14			0.68														(*)			
Hartford, Conn.	6			0.23														0.18			
Hatteras, N. C.	14			0.18														0.16			
Havre, Mont.	10-11			0.14														(*)			
Helena, Mont.	10-11			0.32														(*)			
Houghton, Mich.	10			1.10														(*)			
Houston, Tex.	2			1.62														0.53			
Huron, S. Dak.	27			0.18														(*)			
Independence, Calif.	11			0.34														(*)			
Indianapolis, Ind.	5-6			0.71														(*)			
Iola, Kans.	6			0.16														(*)			
Jacksonville, Fla.	22			2.89														0.59			
Kalispell, Mont.																					
Kansas City, Mo.	5-6			0.11														(*)			
Keokuk, Iowa.	5-6			0.14														(*)			
Key West, Fla.	21	3.20 p.m.	4.40 p.m.	0.62	3.48 p.m.	4.09 p.m.	0.02	0.06	0.15	0.27	0.47	0.53									
Knoxville, Tenn.	9			0.77														0.26			
La Crosse, Wis.	17-18			0.31														(*)			
Lander, Wyo.	7-8			0.24														(*)			
Lansing, Mich.	6			0.45														(*)			
Lewiston, Idaho.	9-10			0.80														(*)			
Lexington, Ky.	6			3.63														0.38			
Lincoln, Nebr.	8-9			0.37														(*)			
Little Rock, Ark.	12-13			1.85														0.36			
Los Angeles, Calif.	4			1.07														0.30			
Louisville, Ky.	12-13			2.18														0.44			
Ludington, Mich.	9			0.41														(*)			
Lynchburg, Va.	9			0.57														0.23			
Macon, Ga.	8			1.43														0.50			

[1] Dec. 9.

* Self-register not in use.

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during December, 1919, at all stations furnished with self-registering gages*—Continued.

Stations.	Date.	Total duration. From—	Total duration. To—	Total amount of precipitation.	Excessive rate. Began—	Excessive rate. Ended—	Amount before excessive rate began.	5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Madison, Wis	6			0.25														(*)			
Marquette, Mich	26-27			0.68														(*)			
Memphis, Tenn	6			0.36														0.27			
Meridian, Miss	8-9	7:05 a.m.	8:00 a.m.	7.01	1:51 p.m.	2:51 p.m.	0.66	0.08	0.12	0.17	0.21	0.24	0.26	0.34	0.43	0.52	0.56	0.80			
					3:39 p.m.	4:51 p.m.	1.68	0.13	0.24	0.29	0.42	0.55	0.61	0.72	0.80	0.84	0.91	1.10	1.45		
					8:32 p.m.	8:49 p.m.	3.94	0.20	0.42	0.75	0.87										
Miami, Fla	14	4:08 p.m.	5:17 p.m.	1.11	4:23 p.m.	5:02 p.m.	0.01	0.31	0.42	0.59	0.68	0.79	0.83	1.01	1.07						
Milwaukee, Wis	6			0.31														(*)			
Minneapolis, Minn	17-18			0.31														(*)			
Mobile, Ala	9	4:25 p.m.	7:40 p.m.	1.78	4:31 p.m.	5:37 p.m.	0.01	0.10	0.17	0.26	0.33	0.39	0.46	0.60	0.80	1.08	1.32	1.58	1.70		
	13	12:15 p.m.	3:15 p.m.	1.62	1:33 p.m.	2:31 p.m.	0.53	0.15	0.19	0.23	0.30	0.46	0.58	0.68	0.71	0.75	0.86	1.04			
Modena, Utah	4			0.20														0.11			
Montgomery, Ala	7	5:30 p.m.	9:00 p.m.	0.76	7:48 p.m.	8:11 p.m.	0.06	0.15	0.30	0.49	0.62	0.66									
	9	6:47 a.m.	1:25 p.m.	3.07	7:27 a.m.	8:12 a.m.	0.12	0.14	0.27	0.49	0.61	0.65	0.81	1.01	1.17	1.29					
		2:20 p.m.	5:40 p.m.	1.67	4:12 p.m.	5:18 p.m.	0.39	0.08	0.18	0.25	0.27	0.31	0.35	0.42	0.52	0.65	0.86	1.12	1.27		
Moorhead, Minn	18			0.25														(*)			
Mount Tamalpais, Calif	11			1.18														0.32			
Nantucket, Mass	13			0.73														0.45			
Nashville, Tenn	13			0.95														0.41			
New Haven, Conn	10			0.77														0.21			
New Orleans, La	9			0.48														0.35			
New York, N. Y	10			0.69														0.27			
Norfolk, Va	14			0.35														0.32			
Northfield, Vt	6-7			0.50														(*)			
North Head, Wash	19			0.77														0.30			
North Platte, Nebr	6			0.17														(*)			
Oklahoma, Okla	4			0.05														(*)			
Omaha, Nebr	8			0.33														(*)			
Oswego, N. Y																					
Palestine, Tex	9			0.59														0.31			
Parkersburg, W. Va	6			1.42														0.34			
Pensacola, Fla	9	7:47 p.m.	8:20 p.m.	0.53	7:47 p.m.	8:07 p.m.	0.00	0.16	0.25	0.42	0.50										
Peoria, Ill	5-6			0.24														(*)			
Philadelphia, Pa	14			0.51														0.27			
Phoenix, Ariz	4			0.11														0.06			
Pierre, S. Dak	31			0.06														(*)			
Pittsburgh, Pa	9			0.54														(*)			
Pocatello, Idaho	6-7			0.85														(*)			
Point Reyes Light, Calif	5			0.85														0.44			
Port Angeles, Wash	24			0.33														0.24			
Port Huron, Mich	6-7			0.19														(*)			
Portland, Me	9			0.58														0.12			
Portland, Oreg	19			0.55														0.14			
Providence, R. I	9-10			0.93														(*)			
Pueblo, Colo	8			0.30														(*)			
Raleigh, N. C	10			0.35														0.31			
Rapid City, S. Dak	30			0.23														(*)			
Reading, Pa	9			0.67														0.14			
Red Bluff, Calif	1			0.18														0.13			
Reno, Nev	2-3			1.34														(*)			
Richmond, Va	8			0.83														0.31			
Rochester, N. Y	17			0.31														(*)			
Roseburg, Oreg	10			1.83														0.28			
Roswell, N. Mex	18			0.21														(*)			
Sacramento, Calif	3			0.74														0.14			
Saginaw, Mich	6-7			0.30														(*)			
St. Joseph, Mo	8-9			0.12														(*)			
St. Louis, Mo	5-6			1.18														(*)			
St. Paul, Minn	17-18			0.35														(*)			
Salt Lake City, Utah	11-12			0.56														(*)			
San Antonio, Tex	2			0.89														0.31			
San Diego, Calif	12			0.76														0.10			
Sand Key, Fla	(‡)			(‡)																	
Sandusky, Ohio	6			0.33														0.08			
Sandy Hook, N. J	10			0.83														0.32			
San Francisco, Calif	10			1.09														0.26			
San Jose, Calif	2			0.70														0.20			
San Luis Obispo, Calif	5			1.51														0.61			
Santa Fe, N. Mex	4-5			0.31														(*)			
Sault Ste. Marie, Mich	14-15			0.56														(*)			
Savannah, Ga	12			0.05														0.02			
Scranton, Pa	13-14			0.94														(*)			
Seattle, Wash	24			0.79														0.18			
Sheridan, Wyo	6-7			0.12														(*)			
Shreveport, La	6	3:50 p.m.	5:35 p.m.	1.00	4:13 p.m.	4:44 p.m.	0.04	0.06	0.23	0.55	0.70	0.72	0.83	0.87							
Sioux City, Iowa	8			0.21														(*)			
Spokane, Wash	16-17			0.40														(*)			
Springfield, Ill	5-6			0.29														(*)			
Springfield, Mo	6			0.17														0.06			
Syracuse, N. Y	9			0.54														(*)			
Tacoma, Wash	23			0.68														0.21			
Tampa, Fla	21			1.15														0.47			
Tatoosh Island, Wash	16			1.54														0.39			
Taylor, Tex	18			1.33														0.30			
Terre Haute, Ind	5-6			0.82														(*)			
Thomasville, Ga	10			0.64														0.29			
Toledo, Ohio	6			0.14														(*)			
Tonopah, Nev	4			0.18														(*)			
Topeka, Kans	8			0.04														(*)			
Trenton, N. J	10			0.73														0.29			
Valentine, Nebr	12			0.09														(*)			
Vicksburg, Miss	9	10:25 a.m.	4:10 p.m.	1.17	11:00 a.m.	11:13 a.m.	0.05	0.36	0.52	0.63											
	13	7:15 a.m.	D.N. p.m.	2.70	8:31 a.m.	10:31 a.m.	0.07	0.17	0.30	0.44	0.52	0.61	0.66	0.71	0.75	0.82	1.02	1.22	1.37	2.02	2.31
Walla Walla, Wash	9-10			0.74														(*)			
Washington, D. C	10			1.07														0.50			
Wausau, Wis	19			0.18														(*)			
Wichita, Kans	5-6			0.12														(*)			
Williston, N. Dak	17			0.06														0.02			
Wilmington, N. C	7			0.59														0.49			
Winnemucca, Nev	11			0.16														0.09			
Wytheville, Va	7			0.60														0.23			
Yankton, S. Dak	8-9			0.07														(*)			
Yellowstone Park, Wyo	11			0.79														(*)			

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* Self-register not in use.

‡ No precipitation occurred during month.

TABLE III.—*Data furnished by the Canadian Meteorological Service, December, 1919.*

Stations.	Altitude above M. S. L. Jan. 1, 1919.	Pressure.			Temperature.						Precipitation.		
		Station reduced to mean of 24 hours.	Sea level reduced to mean of 24 hours.	Departure from normal.	Mean max.+ mean min.÷ 2.	Departure from normal.	Mean maximum.	Mean minimum.	Highest.	Lowest.	Total.	Departure from normal.	Total snowfall.
	Feet.	*Inches.*	*Inches.*	*Inches.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*Inches.*	*Inches.*	*Inches.*
St. Johns, N. F	125	29.61	29.75	−.08	25.9	−2.8	33	19	55	1	6.96	+1.93	32.0
Sydney, C. B. I	48	29.92	29.96	+.07	25.0	−3.2	33	12	55	− 5	4.06	−0.57	27.0
Halifax, N. S	88	29.90	30.01	+.05	24.4	−3.2	33	16	51	9	2.82	−2.30	7.5
Yarmouth, N. S	65	29.94	30.01	+.03	27.0	−3.7	34	20	50	− 1	3.53	−1.51	13.6
Charlottetown, P. E. I	38	29.94	29.98	+.04	19.6	−4.7	27	12	46	−11	2.73	−0.93	8.2
Chatham, N. B	28	29.99	30.02	+.08	11.6	−5.4	21	2	38	−26	1.29	−1.93	8.4
Father Point, Que	20	29.98	30.00	+.05	10.2	−5.2	19	1	39	−22	1.87	−0.96	18.1
Quebec, Que	296	29.72	30.06	+.05	10.0	−5.2	18	2	39	−27	1.54	−2.15	11.9
Montreal, Que	187	29.86	30.08	+.05	15.8	−2.5	23	9	46	−14	1.28	−2.37	11.2
Stonecliffe, Ont	489	29.41	30.05	+.04	6.7	−7.3	20	− 6	42	−28	0.96	−1.53	6:2
Ottawa, Ont	236	29.81	30.10	+.08	14.8	−2.2	23	6	44	−14	0.93	−1.98	8.5
Kingston, Ont	285	29.77	30.11	+.08	20.8	−2.9	29	13	46	−10	1.28	−1.96	9.8
Toronto, Ont	379	29.66	30.09	+.04	22.7	−4.3	30	16	49	− 7	1.00	−1.91	9.6
Cochrane, Ont	930	28.95	....	....	−0.7	....	8	−10	32	−38	2.20	....	22.0
White River, Ont	1,244	28.60	30.00	+.03	− 2.0	−7.7	13	−17	33	−51	1.74	+0.03	17.4
Port Stanley, Ont	592	29.45	30.12	+.05	21.7	−6.7	29	14	44	− 5	1.60	−0.82	14.0
Southampton, Ont	656	29.30	....	....	21.2	−5.5	28	14	44	− 8	3.05	−0.93	29.9
Parry Sound, Ont	688	29.33	30.06	+.05	16.4	−4.8	26	7	41	−25	3.97	−0.51	39.5
Port Arthur, Ont	644	29.33	30.08	+.09	5.4	−8.8	15	− 4	41	−28	0.22	−0.65	2.2
Winnipeg, Man	760	29.24	30.14	+.12	1.8	−2.3	9	− 6	39	−28	0.67	−0.24	6.7
Minnedosa, Man	1,690	28.16	30.10	+.08	1.5	−4.2	− 7	− 7	38	−32	0.80	+0.18	8.0
Le Pas, Man	860	29.01	....	....	−0.1	....	− 8	− 8	36	−30	0.40	....	3.7
Qu'Appelle, Sask	2,115	27.70	30.08	+.08	5.1	−2.3	− 3	− 3	42	−33	0.56	+0.04	5.4
Medicine Hat, Alb	2,144	27.70	30.08	+.11	15.0	−3.0	26	4	53	−36	0.11	−0.44	1.1
Moose Jaw, Sask	1,759	28.09	....	....	10.1	....	19	1	46	−28	0.47	....	3.0
Swift Current, Sask	2,392	27.37	30.09	+.10	11.4	−4.6	21	2	45	−32	0.19	−0.59	1.1
Calgary, Alb	3,428	26.38	30.07	+.13	18.7	+0.2	31	7	56	−32	0.04	−0.55	0.4
Banff, Alb	4,521	25.34	30.15	+.21	12.8	−6.3	22	4	46	−45	0.83	−0.38	7.5
Edmonton, Alb	2,150	27.67	30.08	+.15	11.5	−1.6	20	3	55	−32	0.82	+0.12	8.2
Prince Albert, Sask	1,450	28.42	30.09	+.08	3.1	+0.3	12	− 6	46	−36	0.81	+0.07	5.3
Battleford, Sask	1,592	28.25	30.10	+.11	6.0	+0.6	15	− 3	50	−36	0.38	+0.06	3.8
Kamloops, B. C	1,262	28.96	30.33	+.39	19.8	−9.1	26	14	57	−21	0.54	−0.24	5.0
Victoria, B. C	230	29.85	30.11	+.14	38.0	−3.2	42	34	52	16	4.79	−3.19	0.1
Barkerville, B. C	4,180	....	....	....	....	....	....	....	....	....	....	....	....
Triangle Island, B. C	680	....	....	....	....	....	....	....	....	....	....	....	....
Prince Rupert, B. C	170	....	....	....	....	....	....	....	....	....	....	....	....
Hamilton, Ber	151	29.99	30.15	+.03	66.2	+1.5	71	62	78	54	6.52	+2.03	....

SEISMOLOGY.

W. J. HUMPHREYS, Professor in Charge.

[Dated: Weather Bureau, Washington, D. C., Feb. 3, 1920.]

TABLE I.—*Noninstrumental earthquake reports, December, 1919.*

Day.	Approximate time, Greenwich civil.	Station.	Approximate latitude.	Approximate longitude.	Intensity Rossi-Forel.	Number of shocks.	Duration.	Sounds.	Remarks.	Observer.
		CALIFORNIA.								
1919.	*H. m.*		° ′	° ′			*Sec.*			
Dec. 5	10 34	San Francisco	37 48	122 26	4	1		None	Felt by many	U. S. Weather Bureau.
11	23 29	Santa Cruz	36 55	122 00	5	1		do	Felt by several	W. R. Springer.
		Los Gatos	37 12	121 58	4	1		do	do	F. H. McCullagh.
12	5 38	Aguanga	33 30	117 00	2	1	2	do	Short and sharp	A. J. Berg.
18	7 15	Paso Robles	35 40	120 45	3	1		do	Felt by several	Mrs. A. Z. Campbell.
20	9 30	Santa Rosa	38 30	122 45	4	1		do	do	Press report.
		OREGON.								
26	6 00	Bullrun	45 30	122 12	4			None	Men awakened; shocks throughout night.	

CORRIGENDUM.

REVIEW, August, 1919, page 601:
In the record of the quake on August 18, it should have been reported from 17 to 18 hours *ca.* instead of from 5 to 6 hours.

TABLE 2.—*Instrumental seismological reports, December, 1919.*

(Time used: Mean Greenwich, midnight to midnight. Nomenclature: International.)

[For significance of symbols see REVIEW for January, 1919, p. 59.]

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.

Alabama. *Mobile. Spring Hill College.* Seismic Observatory. Cyril Ruhlman, S. J.

Lat., 30° 41′ 44″ N.; long., 88° 08′ 46″ W. Elevation, 60 meters.

Instrument: Wiechert 80 kg.; astatic, horizontal pendulum.

Date.	Character.	Phase.	Time.	Period T.	A_E	A_N	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Dec. 5		iP?	0 19 22					
		S?	0 20 32	12		*4,000		N component undamped.
		L?	0 22 46	6		*3,500		E only a trace.
		F	0 46 00					

* Trace amplitude.

Alaska. *Sitka. Magnetic Observatory.* U. S. Coast and Geodetic Survey. F. P. Ulrich.

Lat., 57° 03′ 00″ N.; long., 135° 30′ 03″ W. Elevation, 15.2 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants	V	T_0
E	10	18
N	10	16

Date.	Character.	Phase.	Time.	Period T.	A_E	A_N	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Dec. 15		eP_E	1 10 24					Felt at Juneau.
		eP_N	1 10 23					
		M_E	1 11 02	5	10	10		
		F_E	1 12 23					
		F_N	1 11 31					

Arizona. *Tucson. Magnetic Observatory.* U. S. Coast and Geodetic Survey. Wm. H. Cullum.

Lat., 32° 14′ 48″ N.; long., 110° 50′ 06″ W. Elevation, 769.6 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants	V	T_0
E	10	17
N	10	18

Date.	Character.	Phase.	Time.	Period T.	A_E	A_N	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Dec. 18		eP_E	1 24 43					
		eP_N	1 24 40	3				
		L_E	1 29 13					
		L_N	1 29 09					
		M_E	1 29 44		20			
		M_N	1 29 40	4		30		
		C_E	1 33	5				
		C_N	1 31					
		F_E	1 38					
		F_N	1 33					

California. *Berkeley. University of California.*

(*See* Bulletin of the Seismographic Stations, University of California.)

California. *Mount Hamilton. Lick Observatory.*

(*See* Bulletin of the Seismographic Stations, University of California.)

California. *Point Loma. Raja Yoga Academy.* F. J. Dick.

(Report for December, 1919, not received.)

TABLE 2.—*Instrumental seismological reports, December, 1919.*—Continued.

California. *Santa Clara. University of Santa Clara.* J. S. Ricard, S. J.

(*See* Record of the Seismographic Station. University of Santa Clara.)

Colorado. *Denver. Sacred Heart College.* Earthquake Station. A. W. Forstall, S. J.

Lat., 39° 40′ 36″ N.; long., 104° 56′ 54″ W. Elevation, 1,655 meters.

Instrument: Wiechert, 80 kg., astatic, horizontal pendulum.

Date.	Character.*	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Dec. 2		L_E	14 44 ..					Very distinct sinusoidal on E-W. Recurs during day.
		F_E	17 30 ..					
12		L_E	14 20 ..					Distinct but irregular wavelets at intervals.
		F_E	16 50 ..					
18		P_E	1 29 ..					Second P. not discernible.
		M_E	1 31 ..	4	*2,500			
		C_E	1 35 ..					
		F_E	1 38 ..					
22		L_E	2 08 ..					Very small but distinct sinusoidal recurring at intervals.
		F_E	3 50 ..					
23								Activity at intervals during day.
24								Do

* Trace amplitude.

District of Columbia. *Washington. U. S. Weather Bureau.*

Lat., 38° 54′ 12″ N.; long., 77° 03′ 03″ W. Elevation, 21 meters.

Instrument: Marvin (vertical pendulum), undamped. Mechanical registration.

Instrumental constants.. V 110, T_0 6.4

Date.	Character.	Phase.	Time.	Period T.	A_E	A_N	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Dec. 5		P	0 21 25				3,030	
		S	0 26 05					
		F	0 45 ca.					
20		eL	21 35 ..	30				
		L	21 45 ..	20				
		L	21 50 ..	16				
		F	22 20 ca.					

District of Columbia. *Washington. Georgetown University.* F. A. Tondorf, S. J.

Lat., 38° 54′ 25″ N.; long., 77° 04′ 24″ W. Elevation, 42.4 meters. Subsoil: Decayed diorite.

Instruments: Wiechert 200 kg. astatic horizontal pendulum, 80 kg. vertical.

Instrumental constants	V	T_0	ϵ
E	165	5.4	0
N	143	5.2	0
Z	80	3.0	0

Date.	Character.	Phase.	Time.	Period T.	A_E	A_N	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Dec. 5		eP	0 21 23					
		eS	0 26 00					
		eL	0 28 48					
		F	0 49 ..					
14		L	2 15 to 2 34	9				Very heavy micros.
		F	2 42 ..					
18		e	1 26 37					Do.
		Sn?	1 32 00					
		F	1 50 ..					
20		eL	21 35 00					
		L	21 44 16	16				
		F	22 14 ..					

Hawaii. *Honolulu. Magnetic Observatory.* U. S. Coast and Geodetic Survey. Frank Neumann.

Lat., 21° 19′ 12″ N.; long., 158° 03′ 48″ W. Elevation, 15.2 meters.

Instrument: Milne seismograph of the Seismological Committee of the British Association.

Instrumental constant.. T_0 18.4. Sensitivity, 0.40″.

Date.	Character.	Phase.	Time.	Period T.	A_E	A_N	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Dec. 11		P	23 29 54	20				
		eL	23 31 30					
		M	23 33 06	18	*700			
		C	23 36 36					
		F	24 15 ..					
12		P	4 00 48	14				Phases not consistent.
		S?	4 04 24	20				
		eL	4 09 54					
		M	4 16 06	18	*100			
		C	4 18 ..					
		F	4 23 ..					
14		P	1 26 18	17				
		S	1 33 48	17				
		eL	1 38 30					
		M	1 51 06	15	*300			
		C	1 54 ..					
		F	2 31 ..					
17		P	23 55 54					
		L	24 00 00					
18		M	24 04 24	16	*300			
		C	24 08 ..	20				
		F	24 34 ..					
20		eP	20 01 12	19				P confused by air tremors.
		L	20 16 54					
		M	20 23 30	15	*300			
		C	20 34 ..	20				
20		eP	20 58 48	17				P confused by end of previous quake.
		L	21 22 30					
		M	21 27 30	15	*1,000			
		C	21 36 ..	18				
		F	23 26 ..					

* Trace amplitude.

Illinois. *Chicago.* University of Chicago. U. S. Weather Bureau.

Lat., 41° 47′ N.; long., 87° 37′ W. Elevation, 180.1 meters.

Instruments: Two Milne-Shaw horizontal pendulums, 0.45 kg.

Instrumental constants	V	T_0	ϵ	Sensitivity.
E.	150	12	20:1	1″ arc tilt=26.6 mm.
N.	150	8	20:1	1″ arc tilt=13.2 mm.

Date.	Character.	Phase.	Time.	Period T.	A_E	A_N	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Dec. 5		P	0 22 10				2,440	
		S	0 26 09					
		L	0 30 ..	30				
		F	1 ca ..					
14		eL	2					
		L	2 13 ..	18				
		L	2 16 ..	15				
		F	2 50 ca					
18		P	1 26 06					
		S	1 30 30					
		L?	1 33 00					
		F	2 ca ..					
20		eL	20 29 ..					
		L	20 35 ..	26				
		L	20 44 ..	15				
		F						Lost in micros.
20		eL	21 17 ..	ca26				
		L	21 20 30	ca30				
		L	21 35 ..	28				
		L	21 40 ..	24				
		L	21 47 ..	15				
		F	23 10 ca					
26		eL?	17					
		L	17 09 30	22				
		L	17 14 ..	16				
		F	17 40 ca					Do.
27		eL	21 13 ..	18				
		L	21 21 ..	16				
		F	22 ca ..					

TABLE 2.—*Instrumental seismological reports, December, 1919*—Continued.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_A	Amplitude. A_E	Distance.	Remarks.

Kansas. *Lawrence. University of Kansas.* Department of Physics and Astronomy. F. E. Kester.

(Report for December, 1919, not received.)

Maryland. *Cheltenham. Magnetic Observatory.* U. S. Coast and Geodetic Survey. George Hartnell.

(No earthquake recorded during December, 1919.)

Massachusetts. *Cambridge. Harvard University Seismographic Station.* J. B. Woodworth.

(Report for December, 1919, not received.)

Missouri. *Saint Louis. St. Louis University.* Geophysical Observatory. J. B. Goesse, S. J.

(Report for December, 1919, not received.)

New York. *Buffalo. Canisius College.* John A. Curtin, S. J.

(Report for December, 1919, not received.)

New York. *Ithaca. Cornell University.* Heinrich Ries.

Lat., 42° 26′ 58″ N.; long., 76° 29′ 09″ W. Elevation, 242.6 meters.

Instruments: Two Bosch-Omori 25 kg. horizontal pendulums (mechanical registration).

Instrumental constants..	V	T_0	ϵ
E	13	22	4:1
N	14	25	4:1

Date.	Character.	Phase.	Time.	Period T.	A_A	A_E	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Dec. 5	....	e_E.....	0 23 45	4	....	....	......	
		e_N.....	0 27 56	4	....	....	......	
		e_E.....	0 27 58	5	....	....	......	
		F.....	0 50 ..	....	....	....	......	
14	....	eL_E...	2 18 30	18	....	....	......	
		F.....	2 30 ..	....	....	....	......	
20	....	L_E....	21 34 30	38	....	....	......	
		L_E....	21 43 27	22	....	....	......	
		F.....	22 03 ..	....	....	....	......	

New York. *New York. Fordham University.* D. H. Sullivan, S. J.

(Report for December, 1919, not received.)

Panama, Canal Zone. *Balboa Heights.* Governor, Panama Canal.

(Report for December, 1919, not received.)

Porto Rico. *Vieques. Magnetic Observatory.* U. S. Coast and Geodetic Survey. W. M. Hill.

Lat., 18° 09′ N.; long. 65° 27′ W. Elevation, 19.8 meters.

Instruments: Two Bosch-Omori.

Instrumental constants..	V	T_0
E	10	17
N	10	19

Date.	Character.	Phase.	Time.	Period T.	A_A	A_E	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Dec. 5	....	P_E....	0 20 59	5	....	....	......	
		eS_E...	0 24 39	....	....	....	......	
		eN....	0 25 35	....	....	....	......	
		eL_E...	0 25 53	....	....	....	......	
		eL_N...	0 33 00	....	....	....	......	
		M_E....	0 25 59	13	*25	....	......	
		M_N....	0 33 30	15	....	*20	......	
		F_E....	0 36 ..	....	....	....	......	
		F_N....	0 35 ..	....	....	....	......	

* Trace amplitude.

Vermont. *Northfield. U. S. Weather Bureau.* Wm. A. Shaw.

(No earthquake recorded during December, 1919.)

Canada. *Ottawa. Dominion Astronomical Observatory.* Earthquake Station. Otto Klotz.

Lat., 45° 23′ 38″ N.; long., 75° 42′ 57″ W. Elevation, 83 meters.

Instruments: Two Bosch photographic horizontal pendulum, one Spindler & Hoyer 80 kg. vertical seismograph.

	V	T_0
Instrumental constants..	120	26

Date.	Character.	Phase.	Time.	Period T.	A_A	A_E	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Dec. 5	....	O?....	0 14 33	....	....	....	4,400?	
		$P?_N$...	0 22 20	....	....	....	......	
		$PR1_N$?	0 23 38	....	....	....	......	
		S......	0 28 30	....	....	....	......	S and L from the Deformation Instrument with a scale of 18 mm/hr.
		L......	0 34 12	....	....	....	......	
		F......	0 50 ..	....	....	....	......	
14	....	L_E....	{ 2 17 to 2 30 }	16	....	....	......	N-S masked by micros.
		F......	2 40 ..	....	....	....	......	
20	....	eL_E..	{21 28 to 21 40 }	40 20	....	....	......	N-S masked by very heavy micros. The record appears to be that of a severe quake at a distant epicentre.
		L_E....	21 42 ..	17	....	....	......	
		L_E....	21 50 ..	15	....	....	......	
		L_E....	21 59 ..	12	....	....	......	
		F......	22 25 ..	....	....	....	......	

Canada. *Toronto. Dominion Meteorological Service.*

Lat., 43° 40′ 01″ N.; long., 79° 23′ 54″ W. Elevation, 113.7 meters. Subsoil: Sand and clay.

Instrument: Milne horizontal pendulum, North; in the meridian.

Instrumental constant.. T_0 18. Pillar deviation, 1 mm. swing of boom =0.45″.

Date.	Character.	Phase.	Time.	Period T.	A_A	A_E	Distance.	Remarks.
1919			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Dec. 3	....	....	....	....	....	....	......	Marked micros when other station records quake.
5	....	L.....	0 47 42	....	....	....	......	Phases masked by micros.
12	....	L.....	4 32 18	....	....	....	......	Small micros going on.
		L.....	4 34 00	....	*100	....	......	
14	....	eL....	0 58 54	....	....	....	......	
		F.....	1 04 18	....	*200	....	......	
14	....	L.....	1 37 36	....	*100	....	......	
14	....	L.....	2 13 30	....	....	....	......	Earthquakes reported from Alaska on the 14th.
		eL....	2 15 42	....	....	....	......	
		M.....	2 17 24	....	*300	....	......	
		eL....	2 19 30	....	....	....	......	
		F.....	2 35 48	....	....	....	......	
14	....	L.....	3 23 00	....	....	....	......	
		L.....	3 26 30	....	*100	....	......	
		L.....	3 45 54	....	....	....	......	
15	....	L.....	20 18 30	....	....	....	......	
		F.....	20 22 30	....	*50	....	......	
17	....	L.....	0 21 42	....	*50	....	......	
		F.....	....	....	....	....	......	Micros.
20	....	e?....	21 03 30	....	....	....	......	Marked micros render measurements doubtful.
		P?....	21 05 42	....	....	....	......	
		S?....	21 16 06	....	....	....	......	
		L.....	21 29 48	....	....	....	......	
		eL....	21 41 00	....	....	....	......	
		M.....	21 44 06	....	*500	....	9,280	
		eL....	21 51 06	....	....	....	......	
		eL....	22 06 42	....	....	....	......	
		F.....	....	....	....	....	......	Micros.
21	....	L.....	18?48 54	....	*200	....	......	Micros going on.
23	....	eL....	0 22 36	....	....	....	......	Small micros going on.
		L.....	0 26 48	....	*100	....	......	
26	....	L.....	17 16 12	....	....	....	......	Thickening.
		eL....	17 19 36	....	....	....	......	
		M.....	17 22 18	....	*200	....	......	Light turned down at 17 h 37 m.
		F.....	....	....	....	....	......	

* Trace amplitude.

TABLE 2.—*Instrumental seismological reports, December, 1919*—Con.

Date.	Character.		Time.	Period. T.	Amplitude. A_A	A_E	Distance.	Remarks.
			Canada. *Victoria, B. C. Dominion Meteorological Service.*					
			Lat., 48° 24′ N.; long., 123° 19′ W. Elevation, 67.7 meters. Subsoil: Rock.					
			Instrument: Wiechert, vertical: Milne horizontal pendulum, North; in the meridian.					
			Instrumental constant.. T_0 18. Pillar deviation, 1 mm. swing of boom = 0.54″.					
1919.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Dec. 3		P	2 26 26				215	Off Pt. Estevan. Felt there and at Alert Bay Wireless Station.
		L	2 26 55					
		M	2 27 25		*100			
		F	2 30 21					
			VERTICAL.					
		P	*2 24 55*	*2.5*				
		L	*2 25 35*	*3*				
		M	*2 25 45*	3	6			
		F	*2 31 30*					
5		P	0 32 28					
		S	0 37 03					
		L	0 41 29					
		M	0 43 56		*200		2,760	
		F	0 55 44					
12		P	4 22 16					
		M	4 26 42		*200			
		F	4 35 03					
14		P	1 32 02					
		S	1 39 24					
		M	2 00 04		*200			
		F	2 29 05					
14		M	3 34 29		*50			
15		P?	20 16 59					
		M	20 18 57		*200			
		F	20 25 50					
18		P?	0 12 21					
		M	0 20 13		*50			
		F	0 25 08					
18		P	1 34 58					
		L	1 38 54					
		M	1 41 21		*300			
		F	1 49 43					
20		P	21 00 50					Marked micros from 20h 29m to 20h 44m.
		S	21 06 18					
		L	21 15 43					
		M	21 29 36		*500		3,670	
		L	21 38 50					
		L	22 14 20					
		F	22 43 28					
21		M	18 55 28		*50			May not be seismic.
23		P	0 23 38					
		M	0 32 59		*100			
		F	0 41 20					
26		P	16 56 58					
		M	17 01 24		*100			
		F	17 09 51					

* Trace amplitude.

SEISMOLOGICAL DISPATCHES.[1]

London, December 3, 1919.

A serious earthquake occurred in western Asia Minor on Thursday, seven villages in the district of Soma and Balikeari being destroyed, according to advices received here from Constantinople. Many persons were killed and injured, it is stated.—*Associated Press.*

Juneau, Alaska, December 14, 1919.

Juneau and vicinity were rocked at 4:10 p. m. to-day by one of the heaviest earthquakes experienced here in years. Buildings were badly shaken, but no material damage has been reported. It is believed the shocks centered about the Katmai Volcano, near Kodiak, and that the volcano may be in eruption again.—*Associated Press.*

[1] Reported by the organization indicated and collected by the seismological station at Georgetown University, Washington, D. C.

TABLE 3.—*Late reports.* (*Instrumental.*)

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	A_N	Distance.	Remarks.
			Hawaii. *Honolulu. Magnetic Observatory.* U. S. Coast and Geodetic Survey. Frank Neumann.					
			Lat., 21° 19′ 12″ N.; long., 158° 03′ 48″ W. Elevation, 15.2 meters.					
			Instrument: Milne seismograph of the Seismological Committee of the British Association.					
			Instrumental constant.. T_0 18.4 Sensitiveness 0.40″ arc tilt-1 mm.					
1919.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Nov. 5		P	20 36 00	16				
		eL	20 43 06					
		M	20 47 42	15	*100			
		C	20 54 24					
		F	20 58 ..					
6		L	17 32 00					
		M			*100			
		F	17 44 ..					
18		eP	4 22 54					Hourly time breaks missing: time interpolated for an interval of 25 hours.
		L	4 32 24	22				
		M	4 50 18	17	*300			
		C	4 55 ..					
		F	5 16 ..	19				
18		P	23 00 24	15				
		L	23 05 00					
		M	23 11 00	20	*200			
		C	23 19 ..	18				
		F	23 26 ..					
20		iP	14 19 48	19				
		S	14 27 18					
		SR_1	14 32 00	14				Very sharply defined.
		L	14 38 42					
		M	14 42 42	15	*2,000			
		C	14 48 ..	16				
		F	15 36 ..	20				
23		eP	6 17 42	18				Phases indefinite.
		eS	6 23 48					
		L	6 30 30					
		M	6 35 00	17	*700			
		C	6 42 ..	19				
		F	7 25 ..	17				
26		e	8 30 30					
		M	8 31 00		*50			
		F	8 34 ..					

* Trace amplitude.

Porto Rico. *Vieques. Magnetic Observatory.* U. S. Coast and Geodetic Survey. W. M. Hill.

Lat., 19° 09′ N.; Long., 65° 27′ W. Elevation, 19.8 meters.

Instruments: Two Bosch-Omori.

Instrumental constants..		V	T_0
	E	10	17
	N	10	19

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	A_N	Distance.	Remarks.
1919.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Nov. 6		P	7 15 00					Beginning of a series of waves of small amplitude and period about 1s.
		S_N?	7 16 23					
		L_E	7 17 27					
		L_N	7 17 19					
		M_E	7 18 05	14	*60			
		M_N	7 18 02			*50		
		C	7 20 ..					
		F	7 24 ..					
8		eP_E	3 44 39					Felt in several in Porto Rico.
		eP_N	3 45 18			*10		
		F	3 47 ..					
22		P_E	1 09 02					
		P_N	1 08 42					
		M_E	1 09 43		*20			
		M_N	1 10 06	5		*20		
		F	1 14 ..					

* Trace amplitude.

EARTHQUAKES FELT IN THE UNITED STATES DURING 1919.

(Consult also Chart XVII in this issue.)

By W. J. HUMPHREYS, Professor in Charge of Seismological Investigations.

[Dated, Weather Bureau, Washington, Feb. 3, 1920.]

During the year 1919, 86 separate earthquakes strong enough to be noticeable to the senses were reported from different parts of the continental United States, as listed in the accompanying table, and graphically represented (a dot for each *report*) on Chart XVII at the end of this issue of the REVIEW.

Earthquakes of moderate intensities, V–VI (adapted Rossi-Forel scale), accompanied by slight damage or none at all, occurred in Arkansas on November 3; in California on January 25, February 10, 16, 19, 25, March 27, May 2, June 21, 24, July 20, September 12, 15, October 1, 2, and November 25; in Indiana on May 25; in Kansas on May 27; in New Mexico on February 1; and in Virginia on September 5.

The Virginia earthquake, of greatest intensity in the vicinity of Front Royal, Va., is fully treated in the MONTHLY WEATHER REVIEW for November, 1919, page 839.

Places in the United States reporting earthquakes during 1919.

(Consult also Chart XVII in this issue.)

Place.	Approximate latitude N.		Approximate longitude W.		Number of quakes reported.
	°	′	°	′	
ARIZONA.					
Flagstaff	35	12	111	37	1
ARKANSAS.					
Ravenden	36	30	91	11	1
CALIFORNIA.					
Aguanga	33	30	117	00	1
Amos	33	05	115	16	3
Anderson	40	30	122	22	1
Bakersfield	35	22	119	00	2
Barrett	32	43	116	46	2
Berkeley	37	52	122	16	3
Bishop	32	22	118	24	1
Brawley	32	59	115	40	2
Calexico	32	41	115	30	23
Centerville	37	30	122	00	1
Corona	33	52	117	35	1
Eureka	40	48	124	10	6
Fairmont	34	15	118	25	1
Glennville	35	45	118	42	2
Hemet	33	45	116	45	2
Idria	36	24	120	42	1
Imperial	32	50	115	35	1
Kennett	40	45	122	24	3
Lindsay	36	13	119	06	1
Livermore	37	40	121	45	1
Lone Pine	36	37	118	01	5
Lonoak	36	20	120	55	1
Los Angeles	34	03	118	15	1
Los Gatos	37	12	121	58	2
Lucerne Valley	34	27	116	57	1
CALIFORNIA—continued.					
Maricopa	35	05	119	23	3
Napa	38	18	122	20	2
Ojai	34	25	119	12	4
Oak Grove	33	26	116	51	1
Oakland	37	48	122	15	2
Paso Robles	35	40	120	45	1
Peachland	38	23	122	48	1
Petal uma	38	15	122	38	2
Point Reyes	38	02	122	59	1
Redding	40	35	122	25	1
Redlands	34	04	117	12	1
Riverside	33	58	117	21	1
Salinas	36	36	121	40	3
St. Helena	38	41	122	30	1
San Diego	32	43	117	10	1
San Francisco	37	48	122	26	4
San Jose	37	15	121	53	1
San Luis Obispo	35	18	120	39	3
San Pedro	32	45	118	14	2
Santa Barbara	34	23	119	40	1
Santa Cruz	36	55	122	00	1
Santa Rosa	38	30	122	45	1
Spreckles	36	35	121	38	1
Springville	36	07	118	50	1
Squirrel Inn	34	07	117	19	1
Stanford Univ	37	26	122	12	2
Vallejo	38	07	122	18	1
ILLINOIS.					
McLeansboro	38	07	88	33	1
Cairo	37	00	89	10	1
Mount Carmel	38	25	87	48	1
Olney	38	05	88	07	1
Springfield	39	48	89	39	1
INDIANA.					
Bonneville	38	04	87	16	1
Evansville	37	58	87	33	1
Mount Vernon	37	56	87	54	1
New Harmony	38	08	85	56	1
Petersburg	38	31	87	15	1
Princeton	38	23	87	34	1
Vincennes	38	42	87	32	1
Washington	38	40	87	11	1
KANSAS.					
Wichita	37	41	97	20	2
KENTUCKY.					
Hickman	36	34	89	12	4
Bardwell	36	52	89	01	1
Louisville	38	15	85	45	1
Taylorsville	38	02	85	21	1
MISSOURI.					
New Madrid	36	35	89	32	1
NEW MEXICO.					
Socorro	34	08	106	48	1
OREGON.					
Bullrun	45	30	122	12	1
TENNESSEE.					
Tiptonville	36	24	89	30	1
UTAH.					
Moroni	39	32	111	30	1
VIRGINIA.					
Front Royal	38	55	78	10	1

Chart I. Hydrographs of Several Principal Rivers, December, 1919.

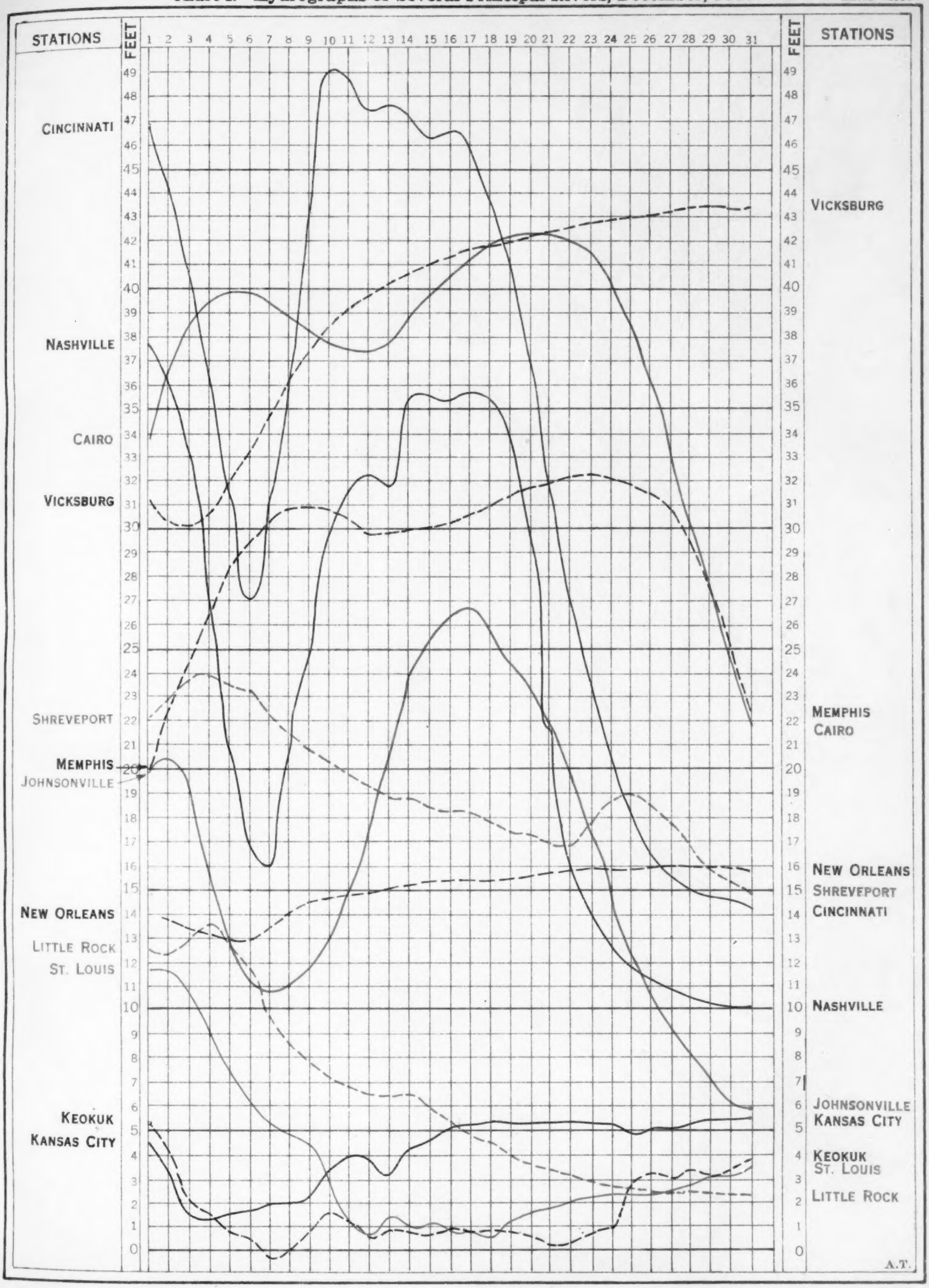


Chart II. Tracks of Centers of High Areas, December, 1919.
(Plotted by R. H. Weightman, Meteorologist.)

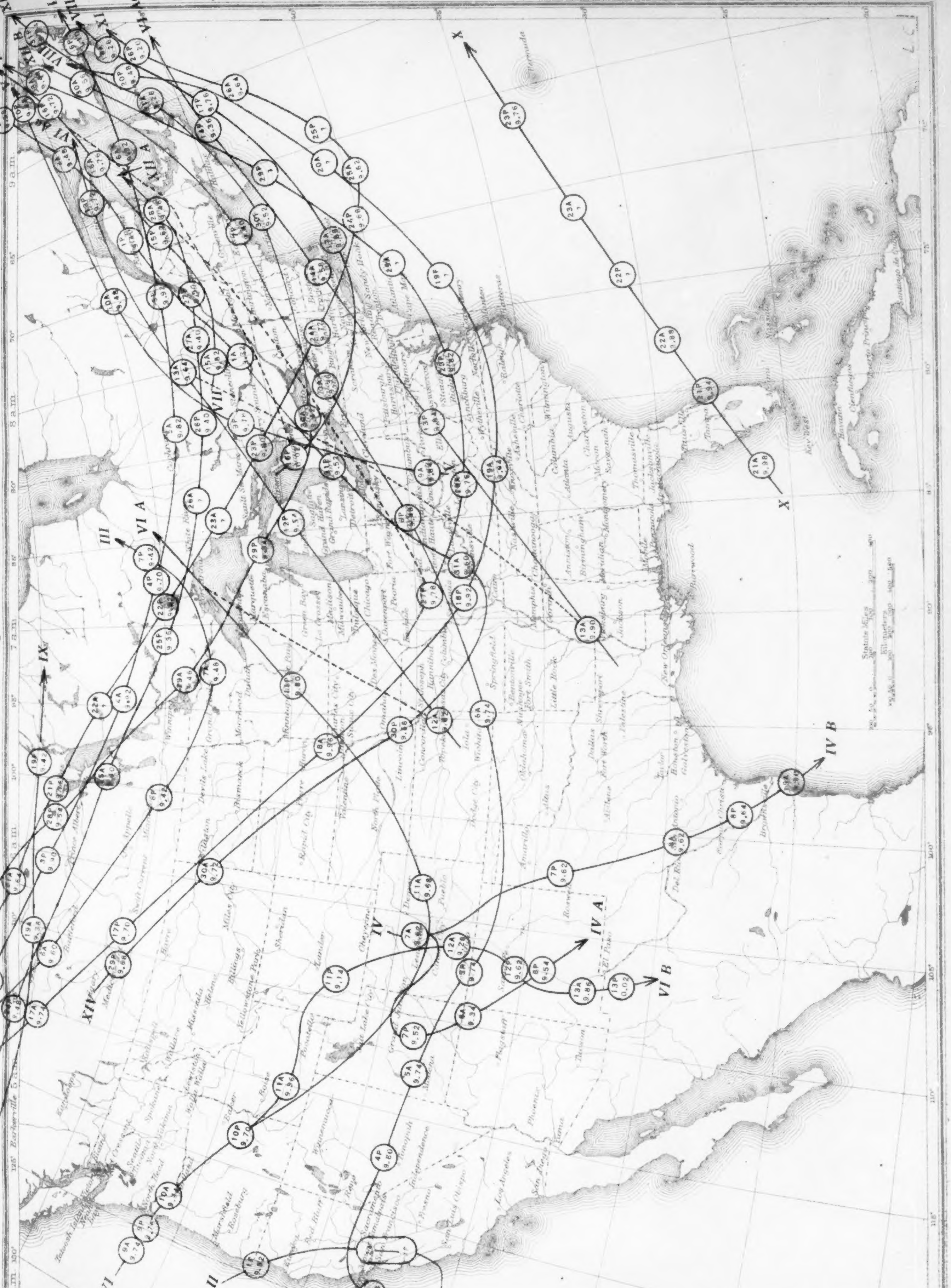
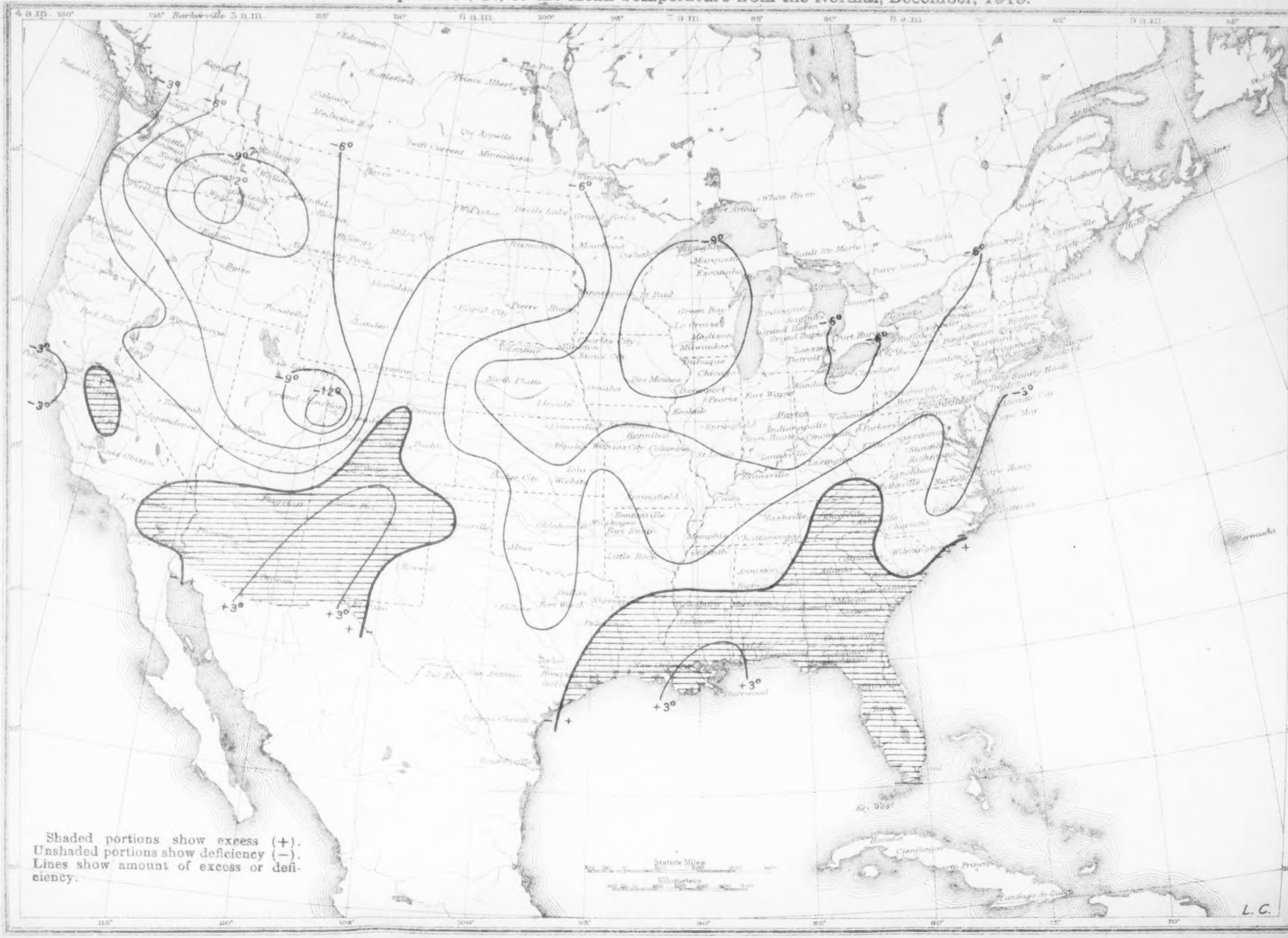


Chart III. Tracks of Centers of Low Areas, December, 1919.
(Plotted by R. H. Weightman, Meteorologist.)

Chart IV. Departure (°F.) of the Mean Temperature from the Normal, December, 1919.



Shaded portions show excess (+). Unshaded portions show deficiency (−). Lines show amount of excess or deficiency.

Chart V. Total Precipitation, Inches, December, 1919.

Chart VI. Percentage of Clear Sky between Sunrise and Sunset, December, 1919.

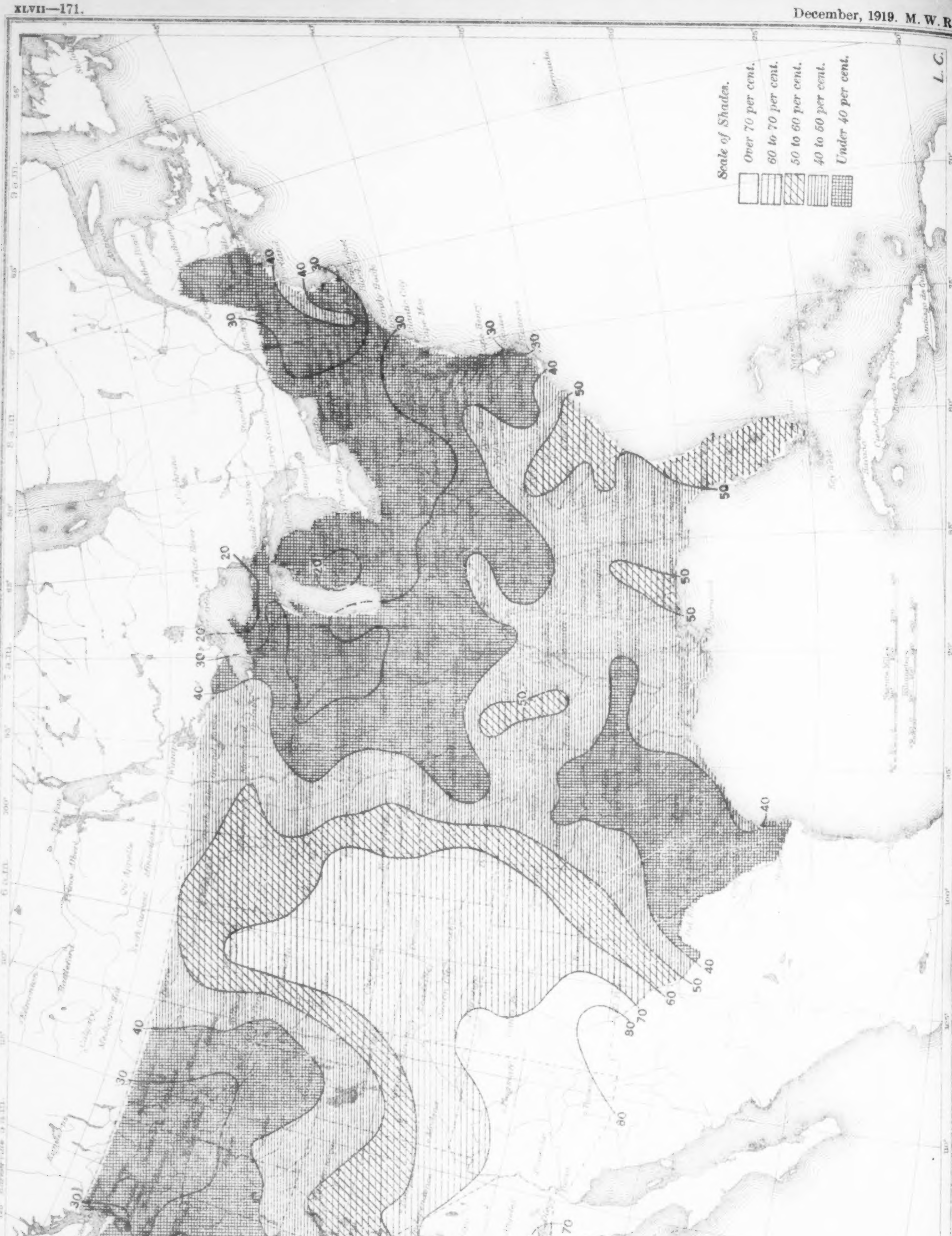


Chart VII. Isobars and Isotherms at Sealevel; Prevailing Winds, December, 1919.

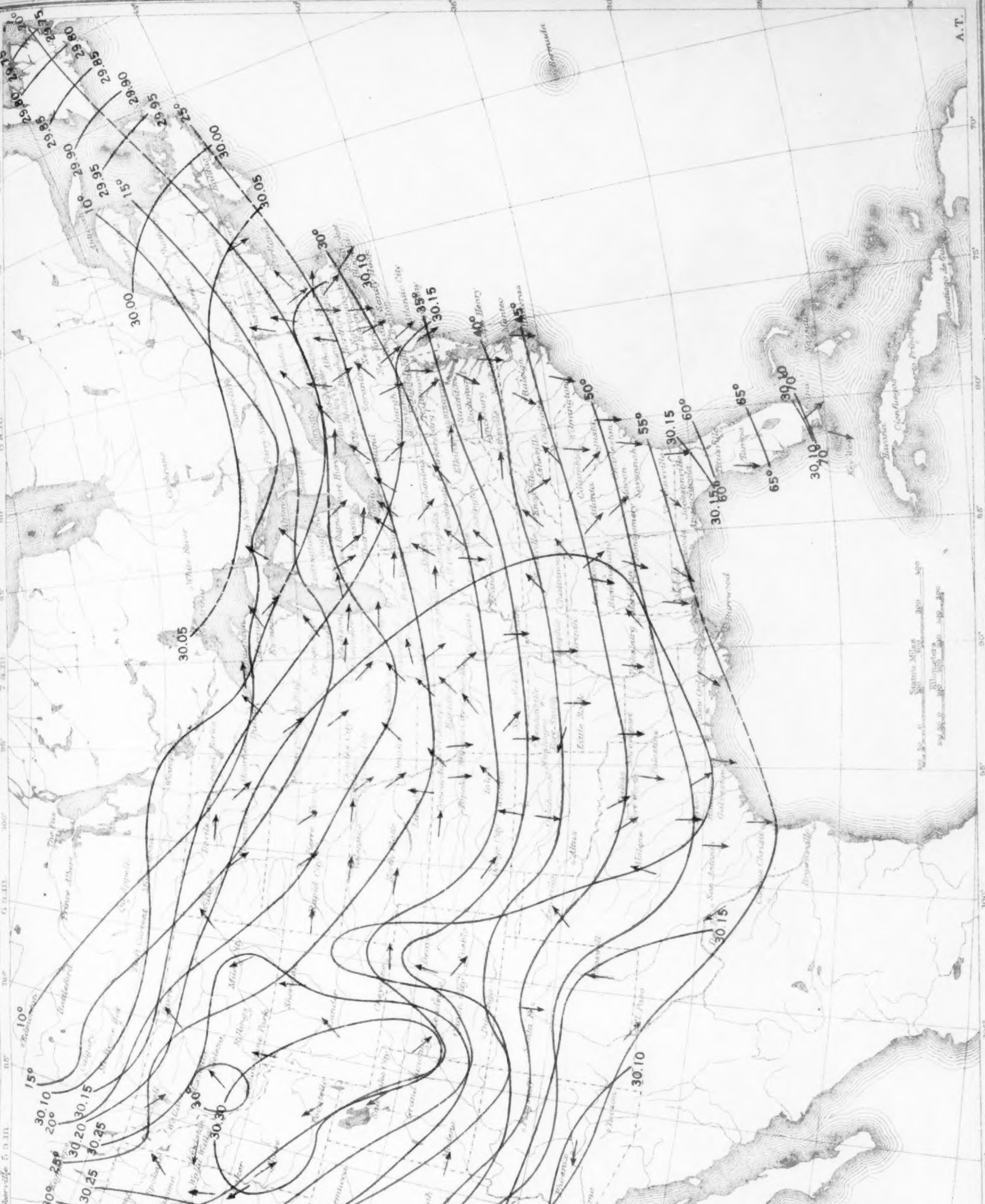


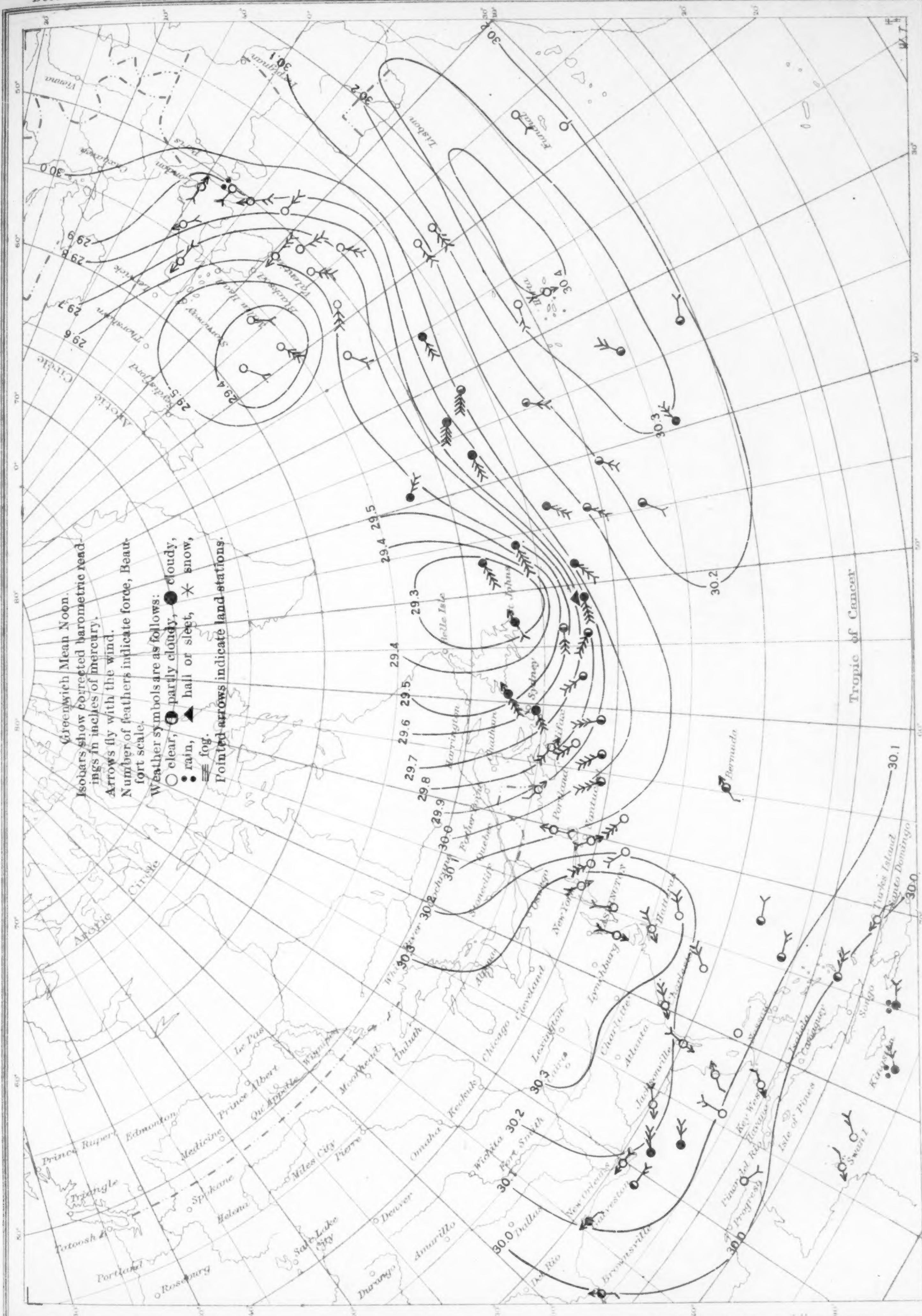
Chart VIII. Total Snowfall, Inches, December, 1919.

Chart IX. Weather Map of North Atlantic Ocean, December 1, 1919.

(Plotted by F. A. Young.)

Chart IX. Weather Map of North Atlantic Ocean, December 1, 1919.

(Plotted by F. A. Young.)



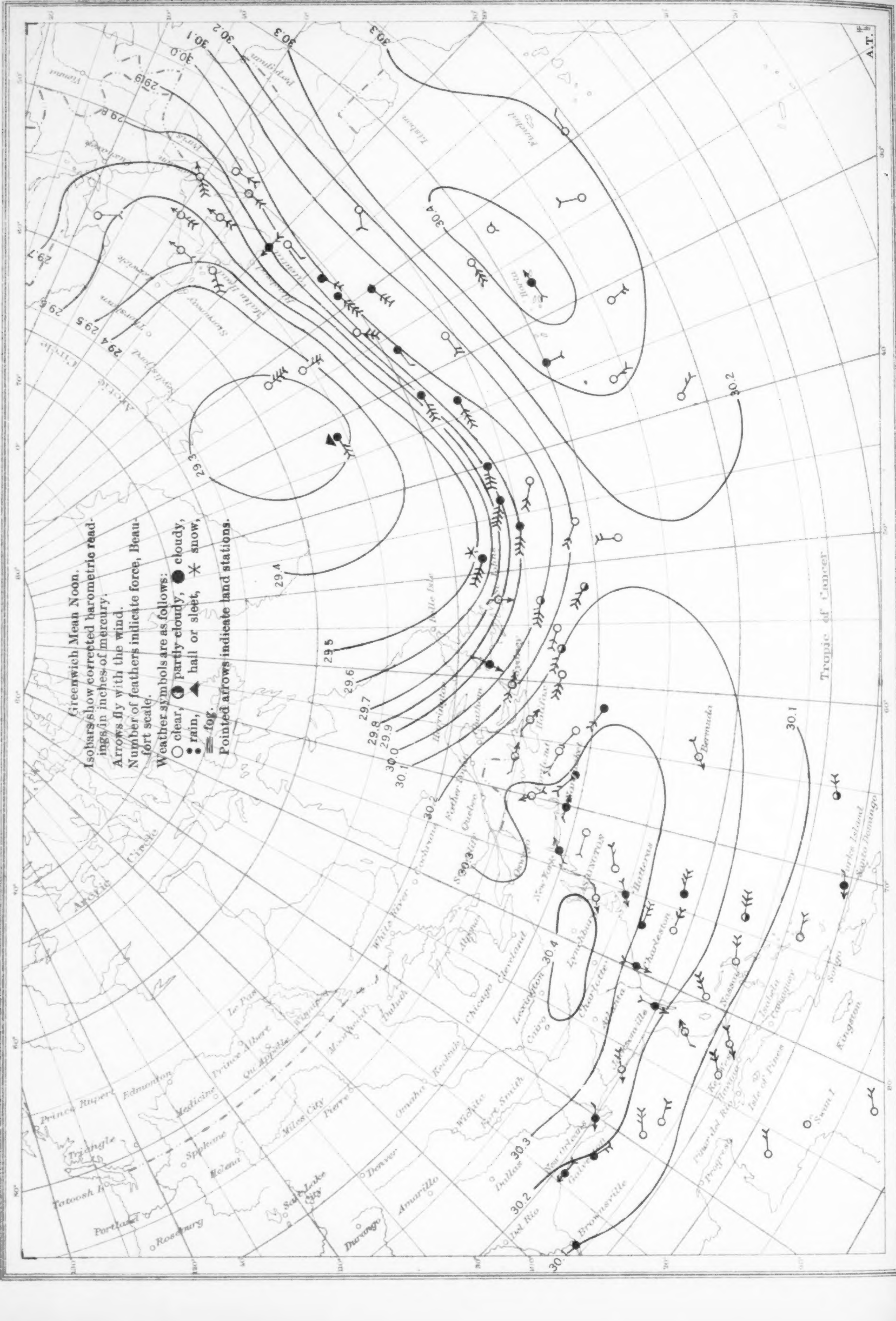


Chart X. Weather Map of North Atlantic Ocean, December 2, 1919.
(Plotted by F. A. Young.)

Chart XI. Weather Map of North Atlantic Ocean, December 3, 1919.
(Plotted by F. A. Young.)

Chart XI. Weather Map of North Atlantic Ocean, December 3, 1919.

(Plotted by F. A. Young.)

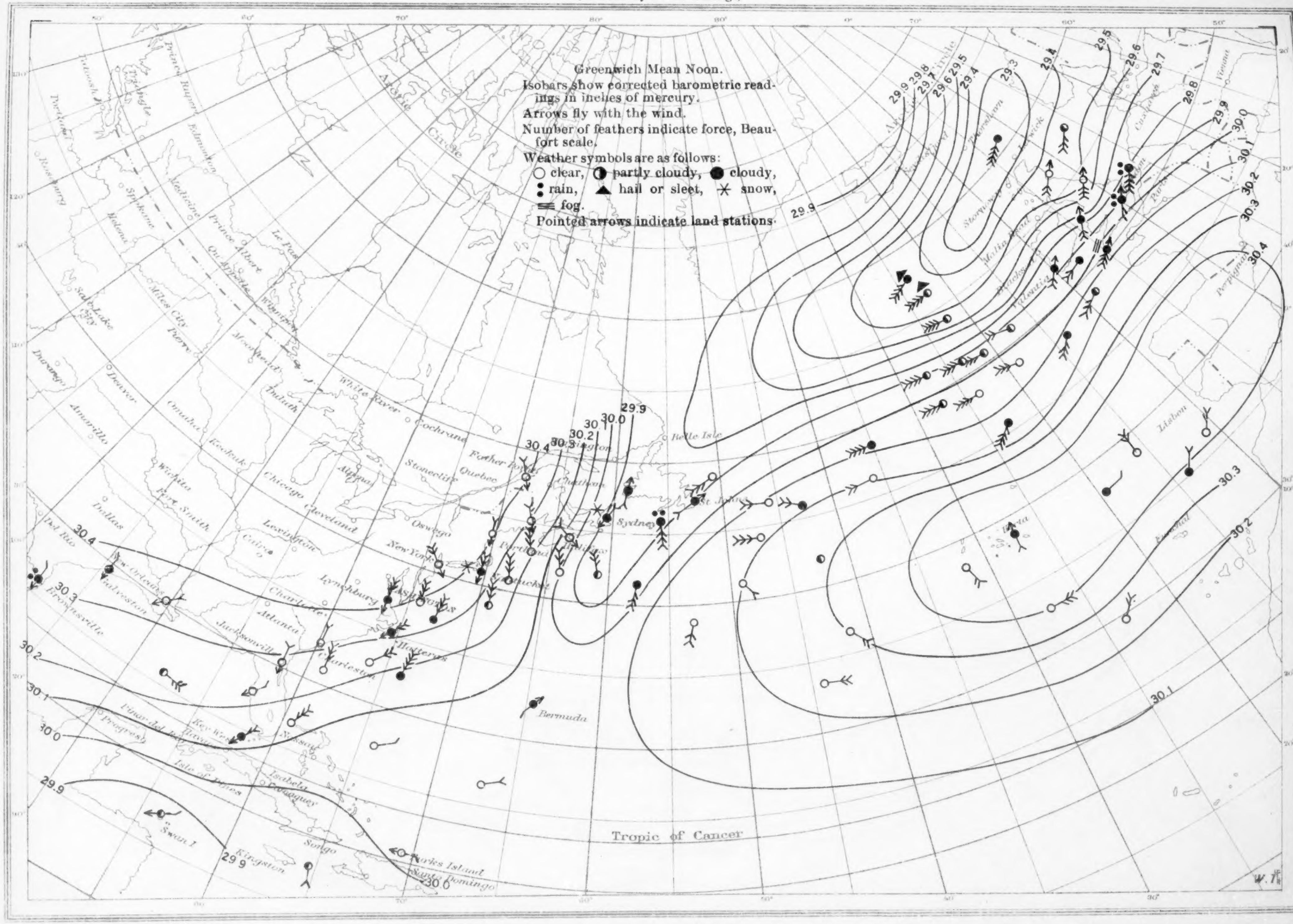


Chart XII. Weather Map of North Atlantic Ocean, December 10, 1919.

(Plotted by F. A. Young.)

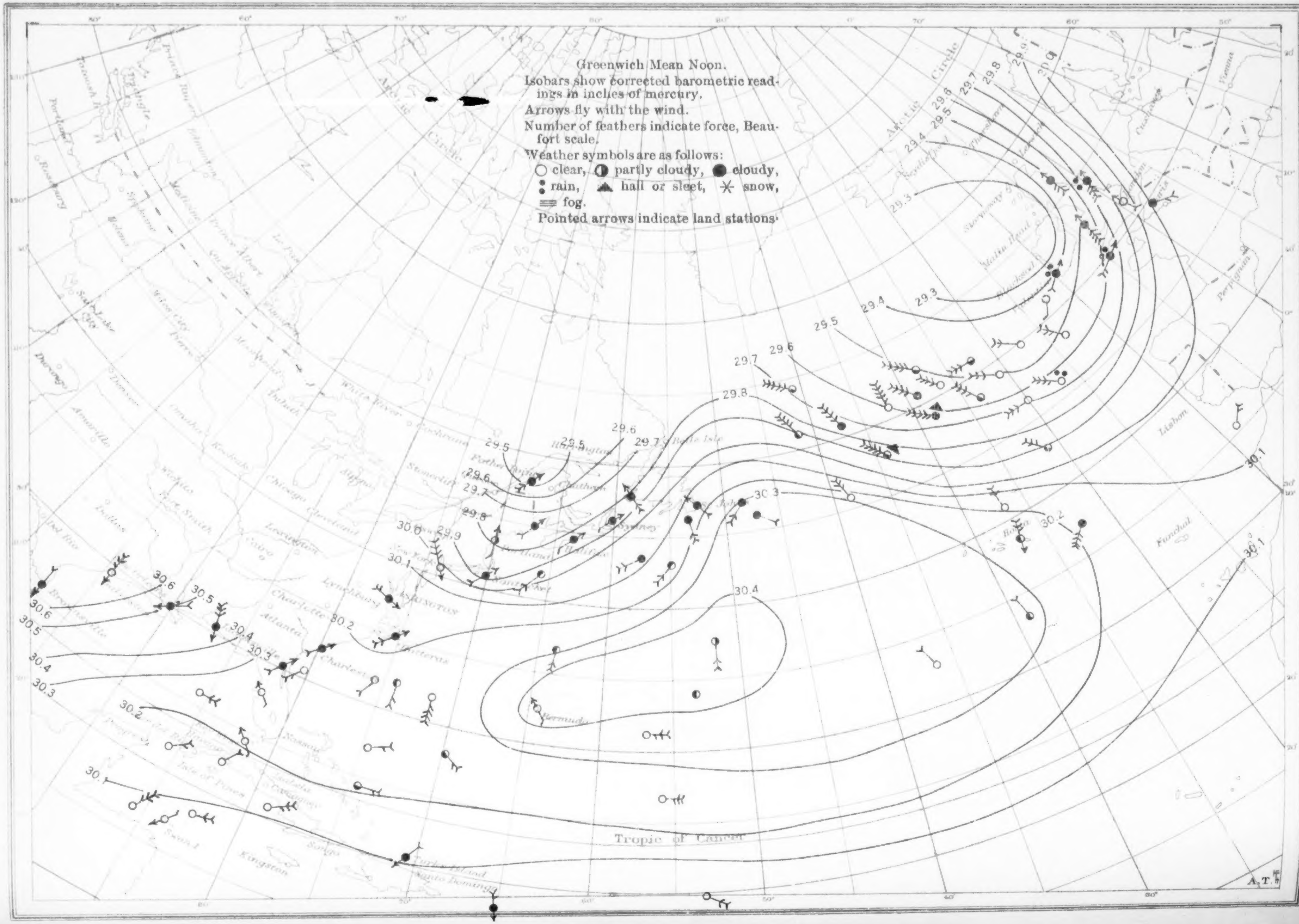
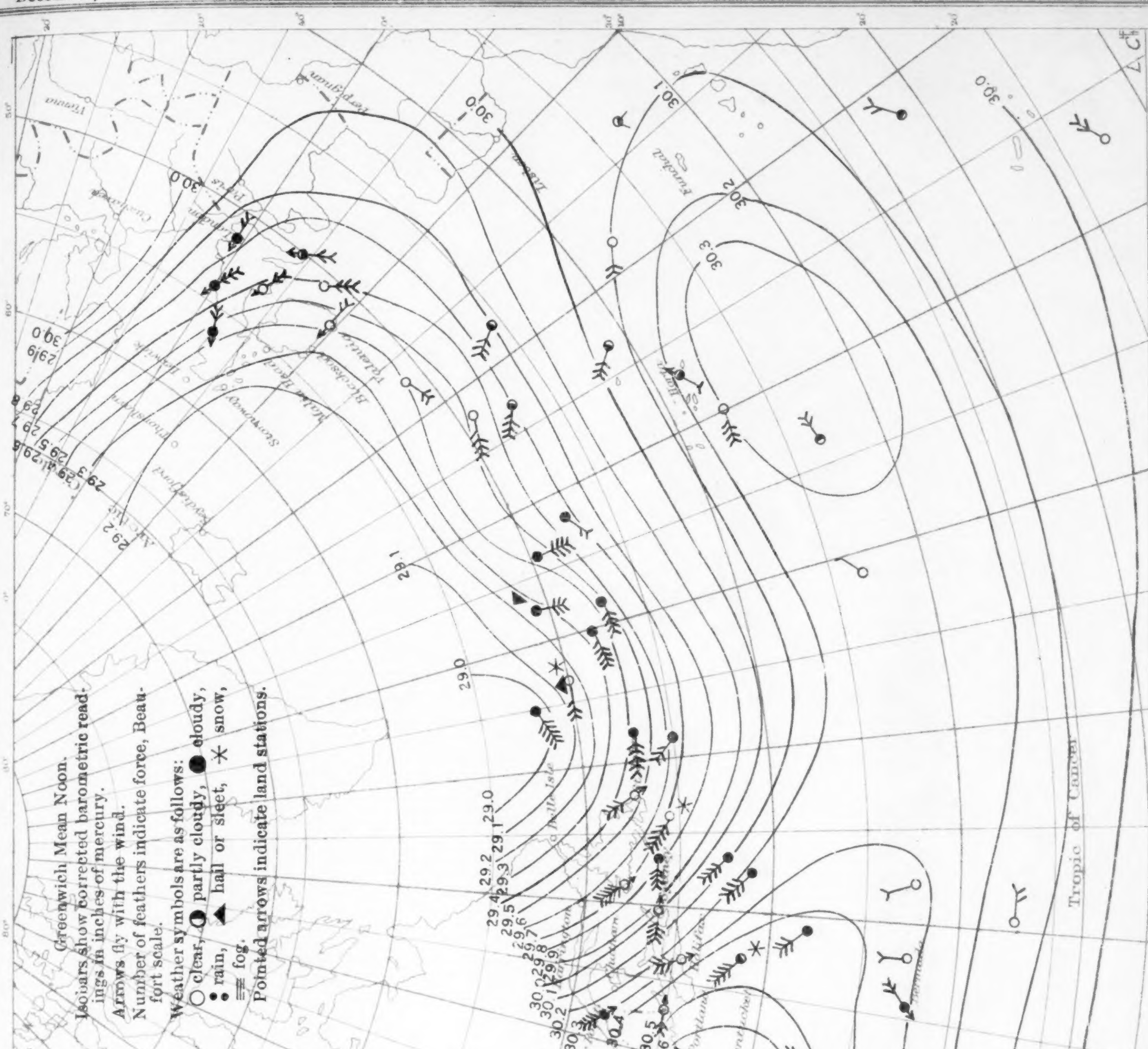


Chart XIII. Weather Map of North Atlantic Ocean, December 11, 1919.

Chart XIII. Weather Map of North Atlantic Ocean, December 11, 1919.

(Plotted by F. A. Young.)



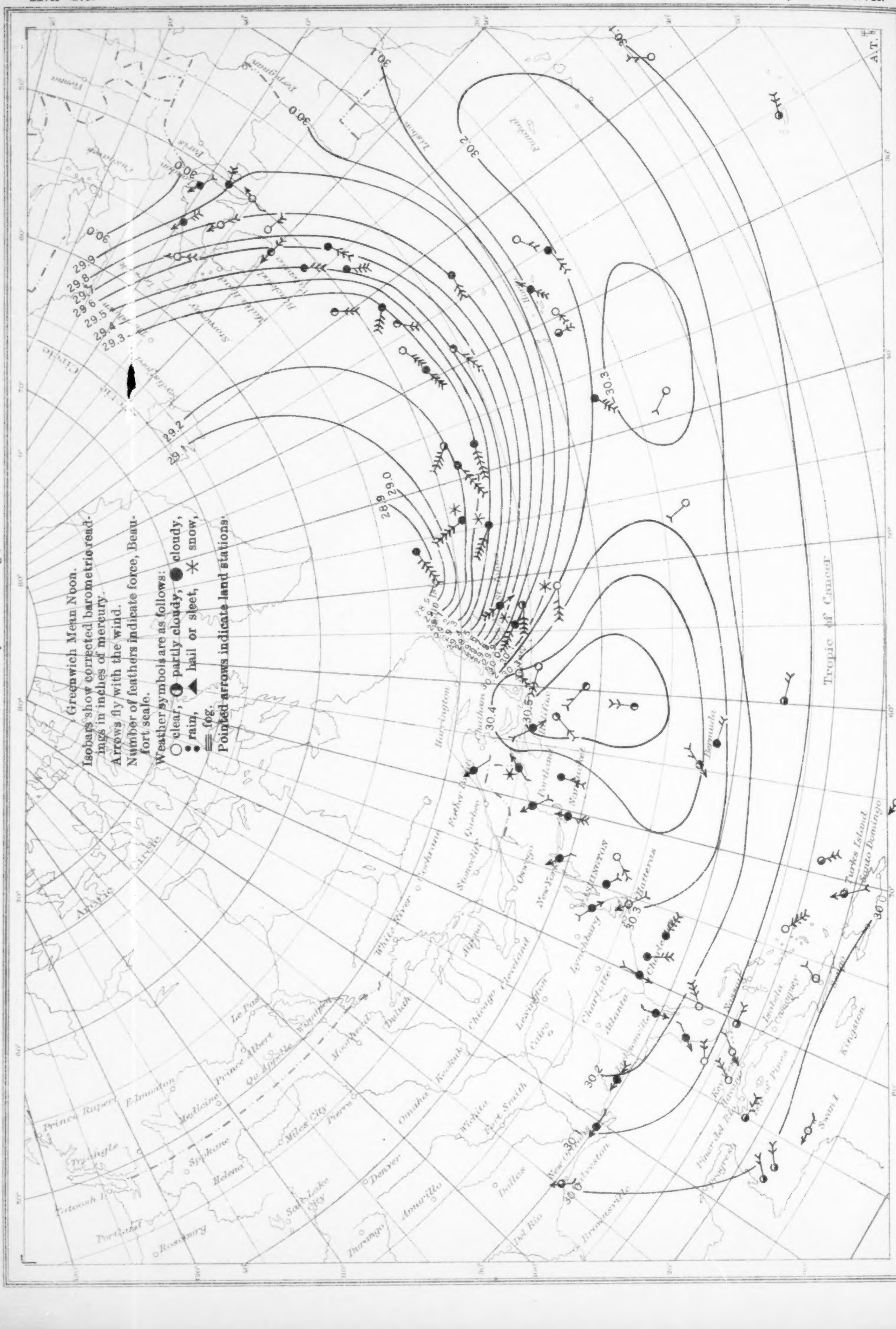


Chart XIV. Weather Map of North Atlantic Ocean, December 12, 1919.
(Plotted by F. A. Young.)

Chart XV. Weather Map of North Atlantic Ocean, December 13, 1919.
(Plotted by F. A. Young.)

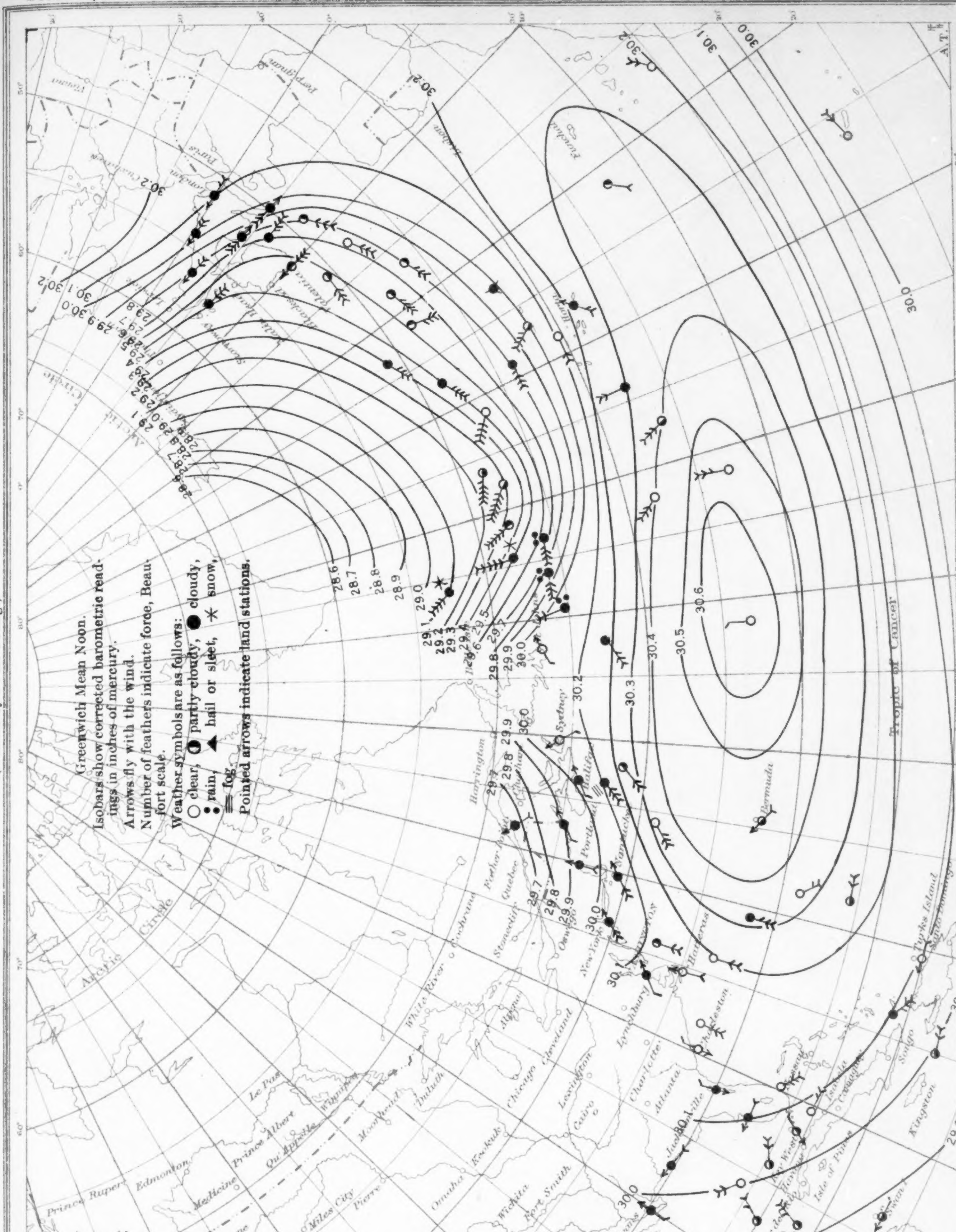


Chart XVI. Weather Map of North Atlantic Ocean, December 31, 1919.

(Plotted by F. A. Young.)

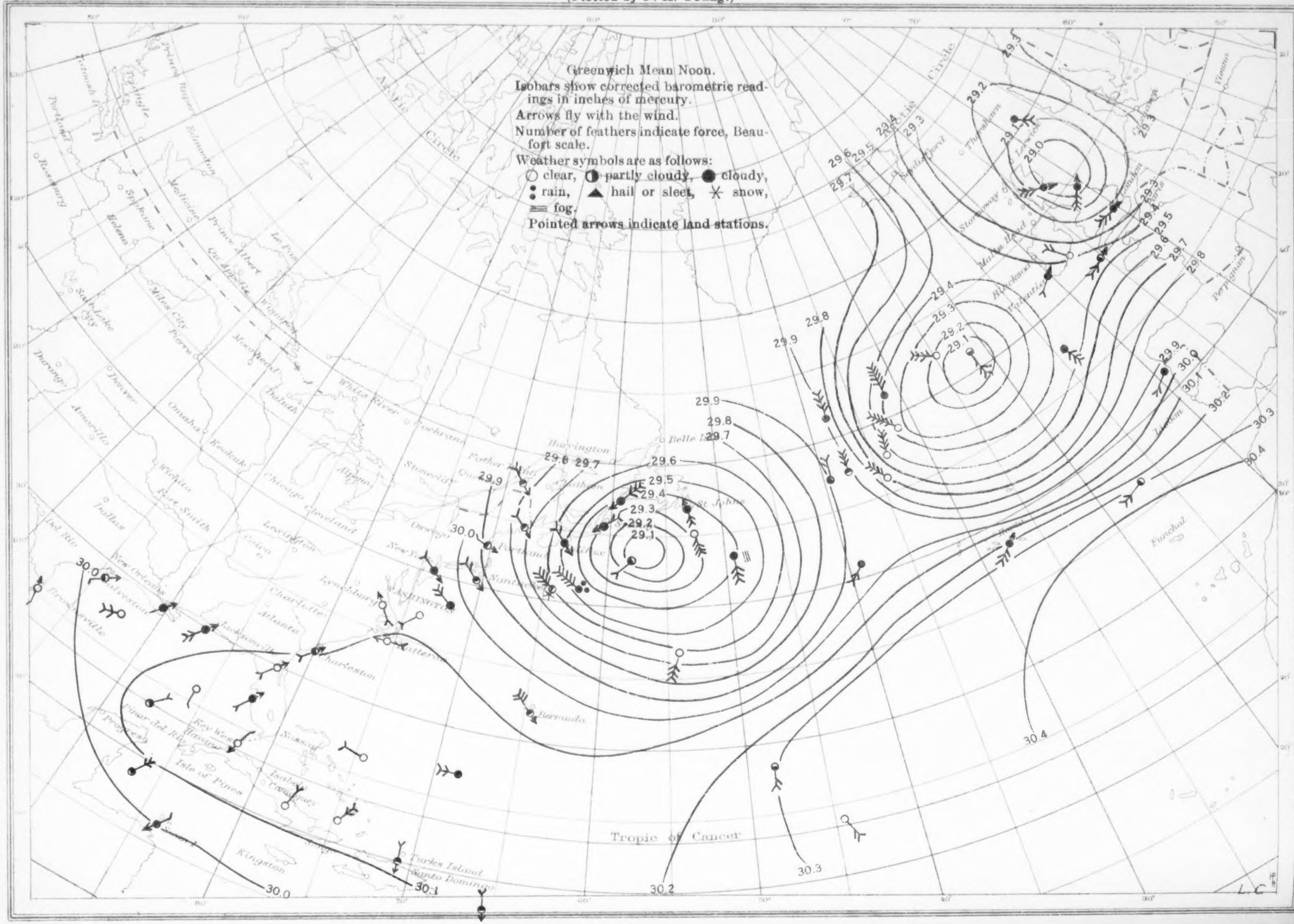


Chart XVII. Earthquakes of 1919.

Chart XVII. Earthquakes of 1919.

DETAILED CLIMATOLOGICAL DATA.

Detailed climatological data for the United States and its outlying territories are collected and published in the monthly reports "Climatological Data," issued at the following Section Centers by the respective officials in charge. They may be secured from the *Superintendent of Documents, Government Printing Office, Washington, D. C.*

State.	Section center.	Official in charge.	State.	Section center.	Official in charge.
Alabama	Montgomery	Patrick H. Smyth.	New England	Boston	John W. Smith.
Arizona	Phoenix	Robert Q. Grant.	New Hampshire (see New England).		
Arkansas	Little Rock	Harvey S. Cole.	New Jersey	Trenton	G. Harold Noyes.
California	San Francisco	Edward A. Beals.	New Mexico	Santa Fe	Charles E. Linney.
Colorado	Denver	Frederick H. Brandenburg.	New York	Ithaca	Wilford M. Wilson.
Connecticut (see New England).			North Carolina	Raleigh	Lee A. Denson.
Delaware (see Maryland).			North Dakota	Bismarck	Orris W. Roberts.
District of Columbia (see Maryland).			Ohio	Columbus	William H. Alexander.
			Oklahoma	Oklahoma	J. Pemberton Slaughter.
Florida	Jacksonville	Alexander J. Mitchell.	Oregon	Portland	Edward L. Wells.
Georgia	Atlanta	Charles F. von Herrmann.	Pennsylvania	Philadelphia	George S. Bliss.
Idaho	Boise	Clinton E. Norquest.	Rhode Island (see New England).		
Illinois	Springfield	Clarence J. Root.			
Indiana	Indianapolis	John H. Armington.	South Carolina	Columbia	Richard H. Sullivan.
Iowa	Des Moines	Charles D. Reed.	South Dakota	Huron	Montello E. Blystone.
Kansas	Topeka	Snowden D. Flora.	Tennessee	Nashville	Roscoe Nunn.
Kentucky	Louisville	Ferdinand J. Walz.	Texas	Houston	Bernard Bunnemeyer.
Louisiana	New Orleans	Isaac M. Cline.	Utah	Salt Lake City	J. Cecil Alter.
Maine (see New England).			Vermont (see New England).		
Maryland	Baltimore	Alfred H. Thiessen.	Virginia	Richmond	Edward A. Evans.
Massachusetts (see New England).			Washington	Seattle	George N. Salisbury.
			West Virginia	Parkersburg	Henry C. Howe.
Michigan	Grand Rapids	Charles F. Schneider.	Wisconsin	Milwaukee	William P. Stewart.
Minnesota	Minneapolis	Ulysses G. Purssell.	Wyoming	Cheyenne	George W. Pitman.
Mississippi	Vicksburg	Robert T. Lindley.			
Missouri	Columbia	George Reeder.			
Montana	Helena	William T. Lathrop.	Alaska	Juneau	M. B. Summers.
Nebraska	Lincoln	George A. Loveland.	Hawaiian Islands	Honolulu	L. H. Daingerfield.
Nevada	Reno	Henry F. Alps.	Porto Rico	San Juan	Oliver L. Fassig.

A monthly volume, collecting all but the last three mentioned under one cover, is issued as above at 35 cents per copy; or subscription per year, 12 monthly copies and annual summary, at $4.

Single sections, 5 cents each.

DECEMBER, 1919.

CONTENTS.

CORRIGENDA.

REVIEW, October, 1919:

Page 696, the legend to figure 1 belongs to figure 2; likewise the legend to figure 2 belongs to figure 1.
Page 701, in legend to figure 1, *for* "degrees Fahrenheit" *read* "inches."
Page 722, 1st column, 3d column of table, *for* "liter" *read* "meter."

REVIEW, November, 1919:

Page 804, figure 1, the legend *should read* "The solid line represents river stages at Portland, Oreg., and the broken line represents computed tides at Astoria."